UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
ESCOLA DE ENGENHARIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

Érico Marcon

DIGITAL PRODUCT-SERVICE SYSTEM: A STUDY ON THE INTERSECTION BETWEEN DIGITIZATION AND SERVITIZATION

Porto Alegre
2019

Érico Marcon

DIGITAL PRODUCT-SERVICE SYSTEM: A STUDY ON THE INTERSECTION BETWEEN DIGITIZATION AND SERVITIZATION

Dissertação submetida ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul como requisito parcial à obtenção do título de Mestre em Engenharia de Produção, modalidade Acadêmica, na área de concentração em Sistemas de Qualidade.
Orientador: Professor Alejandro Germán Frank, Dr.

Porto Alegre
2019

Érico Marcon

Digital Product-Service System: A study on the intersection between digitization and servitization

Esta dissertação foi julgada adequada para a obtenção do título de Mestre em Engenharia de Produção na modalidade Acadêmica e aprovada em sua forma final pelo Orientador e pela Banca Examinadora designada pelo Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul.

_____

Prof. Alejandro Germán Frank, Dr.
Orientador PPGEP/UFRGS

_____

Prof. Flávio Sanson Fogliatto, PhD
Coordenador PPGEP/UFRGS

Banca Examinadora:

Professora Marie-Anne Le Dain, PhD. (GSCOP/INP-France)

Professor Glauco H. S. Mendes, Dr. (PPGEP/UFSCar)

Professor Márcia Elisa Echeveste, Dr. (PPGEP/UFRGS)

“If I have seen further it is by standing on the shoulders of giants”

Isaac Newton

AGRADECIMENTOS

Primeiramente gostaria de agradecer à Deus, pois sem sua benção nada disso seria possível.

Gostaria de agradecer também a meus pais, Sirlei e Adacir que me apoiaram desde o primeiro momento e me deram suporte para poder alcançar essa conquista. Ao Tines, que sempre alegrava os dias de home-office. A minha namorada Fabiana que teve compreensão, me ajudou, me ouviu, me regrou e me incentivou durante todos os momentos, mas que também me inspirou incontáveis vezes. Em especial, também gostaria de agradecer ao meu irmão Arthur que me incentivou a cursar o mestrado e dedicou centenas de horas trabalhando comigo, discutindo, revisando e criticando esse trabalho, sem você isso não seria possível. Amo muito vocês.

Agradeço também aos professores Alejandro e Néstor que desempenharam fundamental papel no desenvolvimento e evolução dessa dissertação, criticando-a e melhorando-a a cada etapa, e também me auxiliando no processo de formação como pesquisador.

Também gostaria de agradecer a todos os colegas de pesquisa do LOPP, professores e amigos que estiveram comigo ao longo dessa caminhada.

A todos vocês, muito obrigado.

CRÉDITOS

A pesquisa apresentada nesta dissertação foi desenvolvida no Núcleo de Engenharia Organizacional da Universidade Federal do Rio Grande do Sul (NEO/UFRGS), como parte integrante do Programa de Pós-graduação em Engenharia de Produção da mesma universidade (PPGEP/UFRGS).

A presente pesquisa forma parte do projeto “Gerenciamento de stakeholders para implementação da Indústria 4.0 em empresas gaúchas: uma análise focada na transformação dos modelos de negócios industriais” financiado pela Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul mediante o edital FAPERGS/Pq-G 2017.

O desenvolvimento da dissertação também foi possível graças à bolsa de mestrado que o candidato recebeu do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) do Ministério da Ciência, Tecnologia, Inovações e Comunicações – Governo Federal do Brasil.

RESUMO

Os temas digitalização e servitização têm sido pesquisados em diversas áreas. Este trabalho foca-se em analisar como a interface entre os dois campos de pesquisa possibilita novas ofertas de valor. Neste sentido, as ofertas servitizadas podem ser impactadas pela digitalização tanto no seu desenvolvimento quanto no seu resultado final. Portanto o primeiro objetivo desta dissertação é compreender quais as barreiras percebidas para cada um dos dois momentos. Os resultados demonstram que as barreiras mais significativas se encontram no uso da digitalização para a inovação da oferta final da servitização. Assim, o segundo objetivo abordado por este estudo é o de compreender como a digitalização e a servitização compõem ofertas de valor por meio de ofertas combinadas, denominadas DPSS, e quais as capabilidades necessárias para sua entrega. Os resultados da revisão da literatura demonstram que as ofertas de DPSS se organizam em três níveis (básico, intermediário e avançado), que, por sua vez são compostas pelos fatores: modelo de negócios ofertado, risco, serviço entregue e uso dos dados. Identificou-se que conforme cresce o nível de DPSS, crescem também as capabilidades necessárias para a sua oferta. Finalmente, com base nos níveis identificados, buscou-se compreender quais os impulsionadores e as barreiras para cada nível de DPSS. Os resultados demonstram que a barreira mais dificulta a oferta de DPSS é a percepção de valor pelo cliente nos níveis mais baixos, devido ao foco da oferta em questões operacionais. Ao passo que, em níveis mais avançados, os impulsionadores se caracterizam justamente pela oferta de valor percebida pelo consumidor, uma vez que o nível avançado se caracteriza pelo foco na entrega de uma solução customizada.

Palavras-chave: Digitalização. servitização. barreiras. sistemas produto-serviço. DPSS.

ABSTRACT

The topics of digitization and servitization have been researched in several areas. In this dissertation the focus is on how the interface between the two fields of allows new value propositions. In this sense, the services offered can be impacted by the digitization both in its development and in its final result. Therefore, the first objective of this dissertation is to understand the perceived barriers in each of the two moments. The results show that the most significant barriers are found in the use of digitization for the innovation of the final offer of servitization. Thus, the second objective addressed by this study is to understand how digitization and servitization convergence, named DPSS, deliver value offers and the necessary capabilities for their delivery. The results of the literature review show that the DPSS offers are organized into three levels (basic, intermediary, and advanced), according to the business model offered, risk, service delivered and data usage. It was identified that as the level of DPSS increases, so do the capabilities required for its supply. Finally, based on the identified levels, we sought to understand the drivers and barriers for each level of DPSS. The results demonstrate that the barrier that most hinders the adoption of DPSS is the perception of value by the customer at the lower levels due to the focus of the offer on operational issues. Whereas at more advanced levels the drivers are characterized by the perceived value by the consumer, as this level is characterized by the focus on delivering a customized solution.

Keywords: Digitization. servitization. Barriers. Product-service systems. DPSS.

SUMÁRIO

1 INTRODUCTION

One of the means manufacturing companies can focus on to reach competitiveness is by leveraging digital technologies, as their effects are able to radically restructure entire industries (Nylén & Holmstrom, 2015). Digitization is understood as the increased use of digital technologies to leverage and harvest value in new ways (Gobble, 2018). In this sense, according to Nylén and Holmstrom (2015), digitization forces companies to challenge prior assumptions about their products or services. In this sense Nylén and Holmstrom (2015) propose that companies that follow a digitization pathway must pay attention to a set of factors such as: the user experience, the value proposition, data exploitation opportunities, development of new skills and the necessary space for improvisation, demonstrating the intrinsic complexity in this process.

In fact, digitization can improve two different moments of innovation, the innovation process and outcome (Nambisan, 2013). Digitization in the innovation outcome can be the use of digital technologies to offering new functionalities and added value to product or service (Nambisan, 2013). Such as the supporting service innovation through digital components that allow availability guarantees, predictive maintenance, condition monitoring, etc. (Lerch and Gotsch, 2015; Porter and Heppelmann, 2015; Ardolino *et al.*, 2017; Grubic, 2018). The use of digital technologies can also be used in the innovation process, as a means to better achieve a more synergic integration between customers' needs and the final offer, this includes a broad range of digital tools such as virtual simulation, social media, PLM, data mining, decision support systems and digital collaborative working systems for making innovation possible (Ardolino et al., 2017; Kiritsis, 2011; Lerch & Gotsch, 2015; Nambisan, 2013)

Meanwhile, another trend, the servitization of manufacturing, has gained wide attention. Servitization is defined as the addition of services to products in order to add value to the offer (Baines, Lightfoot, Benedettini, & Kay, 2009). Servitization has long been studied, since through servitization companies are able to differentiate their offering and improve customer engagement (Vandermerwe & Rada, 1988). In this sense, studies propose that generally companies rely on servitization as a means to generate greater profit margins with constant incomes, though, specially, maintenance and repair offers (Fliess & Lexutt, 2017). The demand for services has also grown due to customers' intention of focusing on their own core activities, outsourcing peripheral

activities (Gebauer, Bravo-Sanchez, & Fleisch, 2007). According to Baines et al. (2007) the servitization process results in a product-service system (PSS), that is a set of product and services capable of, jointly, fulfilling customer's needs. According to Tukker (2004) a PSS is divided into three classifications, based on their business models. The product-oriented business model refers to a PSS that delivers value with services that are attached to a traditional, product-centric offer, such as warranty and maintenance. The use-oriented PSS is not focused on the product itself, since the provider holds the ownership of the product and the value is delivered in the use, such as shared cars or bikes. Finally, in the result-oriented business model the customer and the provider agree on the result expected, however, the means to achieve it are not predetermined.

Thus, companies seeking to servitize their offer can leverage digitization and technological advancements as a means to better deliver their services, due to the possibilities enabled by digital capabilities. Some of the results from digitization are: smart connected products (Porter & Heppelmann, 2014), monitoring, remote access and the resulting advanced business models that are enabled by it, such as improved pay-per-usage (Fliess & Lexutt, 2017). In this sense, our study focuses on the intersection between digitization and servitization as a means to understand how digital technologies can provide gains to a servitized offer. This is due to the possibilities enabled by digital technologies, such as the identification of the user and the products, geolocation, use assessment, monitoring of several indicators, prediction of problems, remote control, among other benefits (Ardolino et al., 2017), which allow servitized companies to provide more accurate (Lerch & Gotsch, 2015) and reliable services (Porter & Heppelmann, 2015; Lerch & Gotsch, 2015; Grubic & Jennions, 2017). Given that companies must take into consideration several factors before innovating through digital means, the complexity in such endeavor is high (Lokuge, Sedera, Grover, & Dongming, 2018).

Posed in the intersection of the digitization and servitization trends, there is the concept of Digital Product-Service Systems (hereafter DPSS) which derives from the concept of PSS. Grounded on the increased interest of PSS (Annarelli, Battistella, & Nonino, 2016), literature started to focus on how servitized strategies could leverage the digitization trend as a means to better deliver value to customers (Belvedere, Grando, & Bielli, 2013; Kowalkowski, Kindström, & Gebauer, 2013). In this sense, DPSS represents an advancement from the PSS concept in which the digital architecture is

responsible for fulfilling customer's needs (Lerch & Gotsch, 2015). Lerch and Gotsch (2015) provide a preliminary descriptive overview specifically addressing how companies can leverage DPSS to deliver different types of services. Their findings show that companies mainly rely on DPSS offer to better deliver maintenance and repair services. The use of data to better design and offer new services and products based on customers' use patterns and big data is only seen on the most advanced DPSS level, the digital brain.

Due to the incipient and rather spread research field, several are the definitions and taxonomies used to address DPSS. In this sense

Table ***1*** provides an overview of how the taxonomies are structured, based on an exploratory literature review on DPSS.

Table 1 - DPSS definitions

	Product	**Service**	**Product-Service System/Servitization**
Digital technologies (includes virtual and synonyms)	(Benssam et al., 2007)	(Herterich, Uebernickel, & Brenner, 2016); (Abdelwahab, Hamdaoui, Guizani, & Rayes, 2014); (Troilo, De Luca, & Guenzi, 2017);(Zhu, Zhao, Tang, & Zhang, 2015)	(Bustinza, Gomes, Vendrell-Herrero, & Tarba, 2018; Holmström, Liotta, & Chaudhuri, 2018; Opazo-Basáez, Vendrell-Herrero, & Bustinza, 2018); (Lerch & Gotsch, 2015); (Coreynen, Matthyssens, & Van Bockhaven, 2015)
Smart/Intelligent	(Porter & Heppelmann, 2015)	(Brad, Murar, & Brad, 2017); (Allmendinger & Lombreglia, 2005; Wuenderlich et al., 2015);(Caggiano, 2018; Candell, Karim, & Söderholm, 2009)	(Chowdhury, Haftor, & Pashkevich, 2018)
Remote maintenance/ diagnostics/ control	(Grubic, 2014, 2018; Grubic & Jennions, 2017; Grubic & Peppard, 2016);	(Jonsson, Holmström, & Lyytinen, 2009; Vardar, Gel, & Fowler, 2007); (Paluch, 2014); (Wu, Zhou, & Xi, 2007); (Jurčević, Boršić, Malarić, & Hegeduš, 2008)	(Ong, West, Lee, & Harrison, 2007); (Diakostefanis, Nikolaidis, Sampath, & Triantafyllou, 2017)
Internet-based (includes ICT, IoT)		(Jiang & Chen, 2007); (Kowalkowski et al., 2013); (Hung, Chen, Ho, & Cheng, 2003);	(Belvedere et al., 2013); (Rymaszewska, Helo, & Gunasekaran, 2017)

/

As

Table *1* demonstrates, the research on the field is spread throughout several taxonomies and approaches. Therefore, the contributions to the field are more hardly

identified and further analysis are hindered, since such a myriad of conceptualizations and names may create separate research fields on the same topic.

1.1 THEME RELEVANCE

DPSS has been increasingly researched in the last years. An exploratory search on the Science Direct database, from 2008 until January 2019, shows the expanding interest on digitization in the servitization field. **Figure 1** portrays the relation between research on servitization alone and research on servitization with digitization in the database.

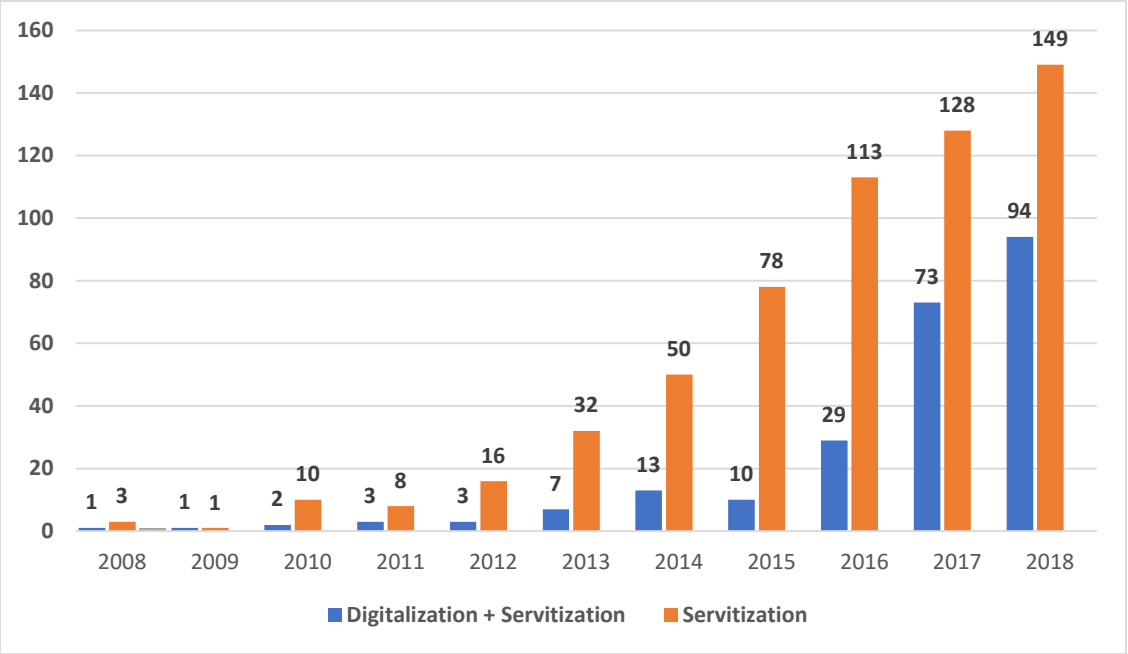


Figure 1- Digitization and servitization research field

The increasing research on the field has driven the choice for this dissertation's theme, as it calls for a deeper analysis on different aspects of the DPSS offer.

1.2 THEME JUSTIFICATION AND OBJECTIVES

This dissertation's theme is justified due to the newness of the field leading to several gaps in research such as a more comprehensive DPSS view approaching not only the offer, but its development, its capabilities (Ardolino et al., 2017; Lerch & Gotsch, 2015), drivers and barriers (Grubic & Jennions, 2017). Also, not enough is known on how manufacturing companies can leverage digitization to increase their service offering (Coreynen, Matthyssens, & Van Bockhaven, 2015), despite the contributions from studies such as Rymaszewska et al. (2017) , Lerch and Gotsch (2015) and Ardolino et al. (2017), they tend to overly focus on the use of few technologies (such as cloud computing, predictive analytics, IoT, etc.) and not on how a set of technologies can improve the aspects that permeate the DPSS offer, such as the use for data, changes or innovation in the business model or the capabilities necessary to its offer (Ardolino et al., 2017; Lerch & Gotsch, 2015).

In this sense, *this dissertation aims to understand how digitization adds value to servitized offers*. In order to achieve this general objective, each of the three articles that compose this dissertation approaches specific, yet complementary, objectives, as shown below.

Article 1 aims *to identify the barriers of digitization by distinguishing the two roles of digital technologies in innovation, namely: the use in the innovation process and the use in the innovation outcome.*

Article 2 aims t*o understand how DPSS offers are organized and to identify the digital capabilities necessary to delivering each DPSS level, as well as to understand how the DPSS offer relates to servitization pathways*

Article 3 aims t*o identify the barriers and the drivers for the offer and the adoption of DPSS, especially in the context of developing countries.*

Thus, the studies are organized in an order from a broader scope to a more specific detailed analysis. That is, the first article addresses a more generic problem, which is the barriers identified by managers and researchers and consultants in the use of digitization for the innovation process and in the innovation outcome of servitized offers. The results showed an incipient understanding of how digitalized offers are organized and what characterizes its offer. In this sense, the following article is focused on the use of digital technologies in the innovation outcome of servitized offers, which presented the most significant barriers. Thus, the article develops a taxonomy as a means to provide a common understanding of the field. Then, building on the findings

of article 1 and 2, the third article seeks to understand what the dimensions of a DPSS are. Additionally, it aims to identify DPSS drivers and barriers.

1.3 METHODS

In its nature, this dissertation is characterized as an applied research, since it aims to generate knowledge for practical applications. Applied research's objectives are to further create knowledge with practical applicability for real specific problems (Yin, 2009). In light of the objectives proposed based on the theoretical gaps found, we followed a qualitative approach, which according to Gil (2010) allows for a greater autonomy for researchers. Malhotra (2010) states that qualitative research aims to provide insights and deeper comprehensions on a given problem, whereas quantitative research methods aim to quantify data.

Still, based on the objectives, this research is characterized as exploratory and descriptive. The exploratory research seeks familiarization with a particular subject and, therefore, it is more versatile and flexible in its structuring (Malhotra, Birks, & Wills, 2010). Thus, it was used to analyze the focus groups (Chapter 1) and the case studies (Chapter 3). Therefore, Malhotra, Birks, and Wills (2010) indicates the use of exploratory research when conducting qualitative studies.

On the other hand, descriptive qualitative research aims to describe a phenomenon and its variables and characteristics (Gil, 2010). Therefore, this dissertation's Chapter 3 relied on descriptive methods to describe the findings from a systematic literature review. Systematic reviews use rigid and transparent algorithms to synthesize theoretical contributions in a given field (Tranfield, Denyer, & Smart, 2003) and, specifically, we used the method in Chapter 3 to subsidize the construction of a framework and the DPSS levels.

The first article was conducted according to the results from two focus groups with a total of 20 participants, 11 consultants and researchers in the first focus group and 9 managers in the second focus group. With a qualitative approach (Gil, 2008), we analyzed the respondents' answers according to the ranking they provided for the most important barriers for digitization in the innovation process and outcome.

The second article was based on a literature review due to the widespread and incipient maturity of the field. Therefore, we followed the steps proposed by Tranfield, Denyer, & Smart (2003), which resulted in 59 articles read and analyzed. The

terminologies, cases and capabilities were mapped and analyzed through a content analysis (Bardin, 1977).

The third article also had a qualitative approach built on the analysis of 6 case studies. Case studies focus on investigating a contemporary phenomenon within its actual context (Yin, 2009) developing theories and enabling the understanding of complex social problems (Eisenhardt & Graebner, 2007) with practical validity (Voss, Tsikriktsis, & Frohlich, 2002). The cases were studied with semi-structured interviews with at least two employees of the company.

Figure 2 graphically summarizes the objectives of each article and the method employed to reach the objectives set.

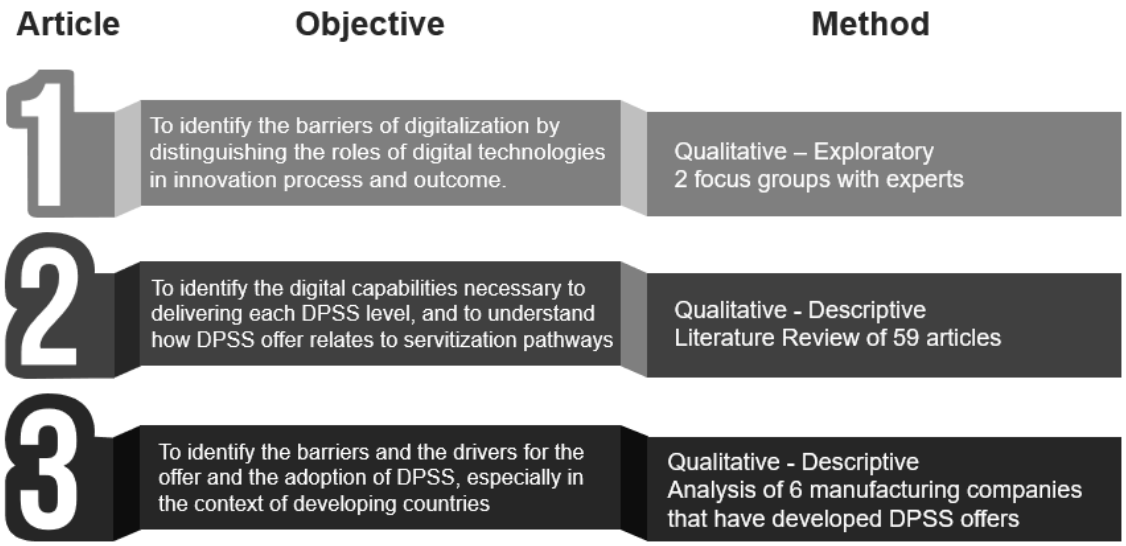


Figure 2 - Summarization of the objectives and methods employed in the dissertation

1.4 STUDY LIMITATIONS

This article presents some limitations that are important to be highlighted. Initially, it is important to mention that the three articles have a qualitative approach. This is due to the necessary exploratory characteristic of this study given the field's newness, which demands an in-depth view of the problem, this is in line with what is proposed by Gil (2008) who states that exploratory studies are able to provide a more precise overview and familiarity to a research field. Although such view was important due to the research maturity, further studies should attempt to provide quantitative views on the DPSS research field such as the one from Belvedere et al. (2013), given

that quantitative studies enable the generalization of the findings, as well as the possibility of approaching a larger set of variables and results.

This dissertation also does not approach the customer view of the DPSS adoption in a profound way, with an exception of the third article which provides a framework with the customer adoption variable. However, this analysis was conducted through providers' point-of-view.

Additionally, this study only approaches the digital capabilities necessary to the provision of DPSS, whereas, the other capabilities were not addressed, which shows a limitation for the complete analysis on the DPSS levels.

1.5 DISSERTATION STRUCTURE

This dissertation is organized into three articles that build on the results from previous articles of the dissertation as a means to reach the general and the specific objectives. In this sense, the first article addresses a broader scope, focusing on the use of digitization to innovation into two different moments, the innovation process and the innovation outcome (Nambisan, 2013). The article, thus, ranks the barriers for the use of digitization on innovation in both moments, with a dual view, through consultants and researchers' view, and managers' view. This study sought to provide a broader, more descriptive overview of the use of digital technologies in the innovation process and outcome toward servitized offers. The results of the article showed an important research and managerial gap, which is the incipient understanding of how digitalized offers are organized and what characterizes its offer. In this sense, the following article is focused on the second use of digitization, as studied in the first chapter of this dissertation, that is, the use of digital technologies in the innovation outcome of a servitized offer. The next article, chapter 3, provides an understanding of how the digitization and the servitization fields merge. Thus, the article develops a taxonomy as a means to provide a common understanding of the field. Additionally, the study identified all the technological capabilities necessary to offering DPSS at different levels.

Finally, grounded on the findings of article 1 and 2, the third article seeks to understand what are the factors that compose a DPSS offer, and what the drivers and barriers to each factor are. In this sense, the article analyzes the singularities for each DPSS level and their differences. In addition, the study also addresses Brazilian's contextual characteristics (barriers or drivers) to a DPSS offer.

Figure 3 illustrates the connection among the articles and how they build on the previous' findings.

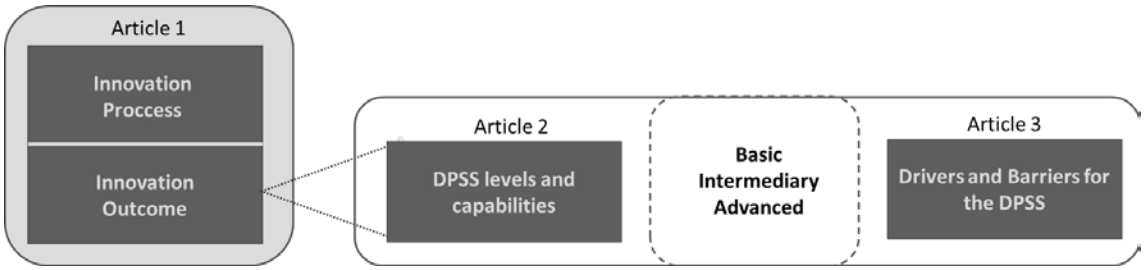


Figure 3 - Articles' connection through the structure of the dissertation

1.6 REFERENCES

Abdelwahab, S., Hamdaoui, B., Guizani, M., & Rayes, A. (2014). Enabling Smart Cloud Services Through Remote Sensing: An Internet of Everything Enabler. *IEEE Internet of Things Journal*, *1*(3), 276–288. https://doi.org/10.1109/JIOT.2014.2325071

Allmendinger, G., & Lombreglia, R. (2005). Four strategies for the age of smart services. *Harvard Business Review*, *83*(10), 131.

Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production*. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2016.08.061

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Ruggeri, C., Ardolino, M., … Gaiardelli, P. (2017). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *7543*(May), 0. https://doi.org/10.1080/00207543.2017.1324224

Baines, T. S., Lightfoot, H. W., Benedettini, O., & Kay, J. M. (2009). The servitization of manufacturing. *Journal of Manufacturing Technology Management*, *20*(5), 547–567. https://doi.org/10.1108/17410380910960984

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., … Wilson, H. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. https://doi.org/10.1243/09544054JEM858

Bardin, L. (1977). *L'analyse de contenu* (Vol. 69). Presses universitaires de France Paris.

Belvedere, V., Grando, A., & Bielli, P. (2013). A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system. *International Journal of Production Research*, *51*(2), 410–426. https://doi.org/10.1080/00207543.2011.648278

Benssam, A., Berger, J., Boukhtouta, A., Debbabi, M., Ray, S., & Sahi, A. (2007). What middleware for network centric operations? *Knowledge-Based Systems*, *20*(3), 255–265. https://doi.org/10.1016/j.knosys.2006.05.020

Brad, S., Murar, M., & Brad, E. (2017). Design of smart connected manufacturing resources to enable changeability, reconfigurability and total-cost-of-ownership models in the factory-of-the-future. *International Journal of Production Research*, *7543*(November), 1–23. https://doi.org/10.1080/00207543.2017.1400705

Caggiano, A. (2018). Cloud-based manufacturing process monitoring for smart diagnosis services. *International Journal of Computer Integrated Manufacturing*, *00*(00), 1–12. https://doi.org/10.1080/0951192X.2018.1425552

Candell, O., Karim, R., & Söderholm, P. (2009). eMaintenance-Information logistics for maintenance support. *Robotics and Computer-Integrated Manufacturing*, *25*(6), 937–944. https://doi.org/10.1016/j.rcim.2009.04.005

Chowdhury, S., Haftor, D., & Pashkevich, N. (2018). Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review. *Procedia CIRP*, *73*, 26–31. https://doi.org/10.1016/j.procir.2018.03.333

Coreynen, W., Matthyssens, P., & Van Bockhaven, W. (2015). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Industrial Marketing Management*, *60*, 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012

Diakostefanis, M., Nikolaidis, T., Sampath, S., & Triantafyllou, T. (2017). Remote operation and monitoring of a micro aero gas turbine. *Aeronautical Journal*, *121*(1242), 1051–1065. https://doi.org/10.1017/aer.2017.50

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: opportunities and challenges diverse. *Academy of Management Journal*, *50*(1), 25–32. https://doi.org/10.1002/job.

Fliess, S., & Lexutt, E. (2017). How to be successful with servitization - Guidelines for research and management. *Industrial Marketing Management*, (November), 0–1. https://doi.org/10.1016/j.indmarman.2017.11.012

Gebauer, H., Bravo-Sanchez, C., & Fleisch, E. (2007). Service strategies in product manufacturing companies. *Business Strategy Series*, *9*(1), 12–20. https://doi.org/10.1108/17515630810850073

Gil, A. C. (2008). *Métodos e técnicas de pesquisa social*. *Journal Of The American Medical Association* (Vol. 264). https://doi.org/10.1590/S1517-97022003000100005

Gil, A. C. (2010). *Como elaborar projetos de pesquisa* (5th ed.). São Paulo: Atlas.

Gobble, M. M. (2018). Digitization, Digitization, and Innovation. *Research-Technology Management*, *61*(4), 56–59. https://doi.org/10.1080/08956308.2018.1471280

Grubic, T. (2014). Servitization and remote monitoring technology. *Journal of Manufacturing Technology Management*, *25*(1), 100–124. https://doi.org/10.1108/JMTM-05-2012-0056

Grubic, T. (2018). Remote monitoring technology and servitization: Exploring the relationship. *Computers in Industry*, *100*, 148–158. https://doi.org/10.1016/j.compind.2018.05.002

Grubic, T., & Jennions, I. (2017). Remote monitoring technology and servitised strategies – factors characterising the organisational application. *International Journal of Production Research*, *7543*(May), 1–17. https://doi.org/10.1080/00207543.2017.1332791

Grubic, T., & Peppard, J. (2016). Servitized manufacturing firms competing through remote monitoring technology An exploratory study. *Journal of Manufacturing Technology Management*, *27*(2), 154–184. https://doi.org/10.1108/JMTM-05-2014-0061

Herterich, M. M., Uebernickel, F., & Brenner, W. (2016). Stepwise Evolution of Capabilities for Harnessing Digital Data Streams in Data-Driven Industrial Services. *MIS Quarterly Executive*, *15*(4), 297–318. Retrieved from http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=bth%7B&%7DAN=120565633%7B&%7Dsite=ehost-live

Hung, M. H., Chen, K. Y., Ho, R. W., & Cheng, F. T. (2003). Development of an e-Diagnostics/Maintenance framework for semiconductor factories with security considerations. *Advanced Engineering Informatics*, *17*(3–4), 165–178. https://doi.org/10.1016/j.aei.2004.07.004

Jiang, P., & Chen, B. (2007). Some key issues on enabling e-manufacturing as a part of product-driven e-business process via e-service. *International Journal of Manufacturing Technology and Management*, *10*(4), 380–399. https://doi.org/10.1504/IJMTM.2007.012156

Jonsson, K., Holmström, J., & Lyytinen, K. (2009). Turn to the material: Remote diagnostics systems and new forms of boundary-spanning. *Information and Organization*, *19*(4), 233–252. https://doi.org/10.1016/j.infoandorg.2009.07.001

Jurčević, M., Boršić, M., Malarić, R., & Hegeduš, H. (2008). Internet-enabled calibration services: Design of a secure calibration system. *IEEE Transactions on Instrumentation and Measurement*, *57*(9), 2012–2018. https://doi.org/10.1109/TIM.2008.919019

Kiritsis, D. (2011). Closed-loop PLM for intelligent products in the era of the Internet of things. *CAD Computer Aided Design*, *43*(5), 479–501. https://doi.org/10.1016/j.cad.2010.03.002

Kowalkowski, C., Kindström, D., & Gebauer, H. (2013). ICT as a catalyst for service business orientation. *Journal of Business & Industrial Marketing*, *28*(6), 506–513. https://doi.org/10.1108/JBIM-04-2013-0096

Lerch, C., & Gotsch, M. (2015). Digitalized Product-Service Systems in Manufacturing Firms: A Case Study Analysis. *Research-Technology Management*, *58*(5), 45–52. https://doi.org/10.5437/08956308X5805357

Malhotra, N. K., Birks, D. F., & Wills, P. (2010). *Marketing Research : An Applied Approach*. *Marketing Research*.

Nambisan, S. (2013). Information Technology and Product/Service Innovation: A Brief Assessment and Some Suggestions for Future Research. *Journal of the Association for Information Systems*, *14*(4), 215–226. https://doi.org/10.17705/1jais.00327

Nylén, D., & Holmstrom, J. (2015). Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Business Horizons*, *58*(1), 57–67. https://doi.org/10.1016/j.bushor.2014.09.001

Ong, M. H., West, A. A., Lee, S. M., & Harrison, R. (2007). The opportunities for multimedia supported remote maintenance provided by an implementation of a component-based system in the automotive domain. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(5), 787–798. https://doi.org/10.1243/09544054JEM620

Paluch, S. (2014). Customer expectations of remote maintenance services in the medical equipment industry. *Journal of Service Management*, *25*(5), 639–653. https://doi.org/10.1108/JOSM-07-2013-0195

Porter, M., & Heppelmann, J. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, *92*(11), 64–88.

Porter, M., & Heppelmann, J. (2015). How Smart, Connected Products are Transforming Companies. *Harvard Business Review*, *1*(OCTOBER). https://doi.org/10.1017/CBO9781107415324.004

Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics*, *192*, 92–105. https://doi.org/10.1016/j.ijpe.2017.02.016

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing

Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Troilo, G., De Luca, L. M., & Guenzi, P. (2017). Linking Data-Rich Environments with Service Innovation in Incumbent Firms: A Conceptual Framework and Research Propositions. *Journal of Product Innovation Management*, *34*(5), 617–639. https://doi.org/10.1111/jpim.12395

Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment*, *13*(4), 246–260. https://doi.org/10.1002/bse.414

Vandermerwe, S., & Rada, J. (1988). Servitization of business: Adding value by adding services. *European Management Journal*, 314–324. https://doi.org/10.1016/0263-2373(88)90033-3

Vardar, C., Gel, E. S., & Fowler, J. W. (2007). A framework for evaluating remote diagnostics investment decisions for semiconductor equipment suppliers. *European Journal of Operational Research*, *180*(3), 1411–1426. https://doi.org/10.1016/j.ejor.2006.05.020

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, *22*(2), 195–219. https://doi.org/10.1108/01443570210414329

Wu, B., Zhou, B., & Xi, L. (2007). Remote multi-robot monitoring and control system based on MMS and web services. *Industrial Robot: An International Journal*, *34*(3), 225–239. https://doi.org/10.1108/01439910710738863

Wuenderlich, N. V, Heinonen, K., Ostrom, A. L., Patricio, L., Sousa, R., Voss, C., & Lemmink, J. G. A. M. (2015). "Futurizing" smart service: implications for service researchers and managers. *Journal of Services Marketing*, *29*(6/7), 442–447. https://doi.org/10.1108/JSM-01-2015-0040

Yin, R. K. (2009). Case study research: Design and methods (applied social research methods). *London and Singapore: Sage*.

Zhu, Z., Zhao, J., Tang, X., & Zhang, Y. (2015). Leveraging e-business process for business value: A layered structure perspective. *Information and Management*, *52*(6), 679–691. https://doi.org/10.1016/j.im.2015.05.004

2 ARTICLE 1 – BARRIERS FOR THE DIGITIZATION OF SERVITIZATION

***This paper has been submitted to the 11th CIRP Conference on Industrial Product-Service Systems for publication at Procedia CIRP**

Abstract

The use of digital technologies can increase firms' performance and competitiveness. In product-service system context, digital technologies can improve both the innovation process, by facilitating the orchestration and collaboration, and the outcome, since they can offer new functionalities and deliver value through a digital solution. Although the benefits and possibilities of digital technologies in the PSS have been previously addressed by research, several questions and gaps regarding the barriers encountered in the digitization of the innovation process and the innovation outcome remain unanswered or unfulfilled. To that end, this article applied a qualitative approach with two focus groups to understand what barriers are perceived by researchers and consultants, and managers. Results show that consultants perceive more strategic barriers, whereas managers perceive more operational barriers. We also found that financial and data security barriers are among the most important for digitization. Our results show that outcome barriers are perceived to a higher extent than process ones. In this sense, in the innovation process, barriers are more focused on operational and human-resource aspects, such as data security, and competences and training. Whereas in the outcome, the barriers are more related to strategic and operational aspects, namely: market acceptance, financial and short-term vision.

Keywords: digitization; servitization; product-service systems; digital product-service systems; technology

1 INTRODUCTION AND THEORETICAL BACKGROUND

Digital transformation, or Digitization, is understood as the process of using digital technologies to create and obtain value in new ways (Frank et al. 2019; Gobble 2018). It is a new trend that has been enabled by the miniaturization of hardware, powerful microprocessors, and wide access to the internet (Dalenogare, Benitez, Ayala, & Frank, 2018; Porter & Heppelmann, 2015; Yoo, Boland, Lyytinen, & Majchrzak, 2012). Thus, companies increase not only their performance but also their competitiveness when digitalizing (Ferreira, Fernandes, & Ferreira, 2018). However, digitization demands a holistic view in its management for navigating in this rapidly changing innovation landscape (Nylén & Holmstrom, 2015). In this sense, the dimensions that impact digitization are product, environment, and organization impact (Frank et al. 2019; Nylén and Holmstrom 2015). Product is determined by user

experience (i.e. usability and aesthetics) and value proposition, such as segmentation and strategic pricing; environment demands a scanning of the digital innovation environment, such as new digital devices and channels. Finally, the organization encompasses two areas: skills and improvisation. Skills are the internal and external skills necessary for the new digital roles, while improvisation is the necessary organizational space to assure the maximization of creativity. These aspects show the broadness and complexity of the digitization field, in which several factors may affect its outcomes.

By embracing digital technologies (DT), firms are more easily able to boost their servitization strategy (Frank, Dalenogare, and Ayala 2019; Pagoropoulos, Maier, and McAloone 2017). The use of DT could lead to innovation outcomes or facilitate the innovation process (Nambisan, 2013). The digitization in the innovation outcome is comprehended by offering new functionalities and added value to product or service (Nambisan, 2013). Such impacts can be information technologies supporting service innovation through digital components that allow the provision of services (Pagoropoulos et al., 2017), such as availability guarantees, predictive maintenance, condition monitoring, etc. (Coreynen, Matthyssens, & Van Bockhaven, 2015; Lerch & Gotsch, 2015; Paluch, 2014).

Also, due to its possibilities digitization is impacting and enabling innovative business models and products and services (Gobble, 2018; Nylén & Holmstrom, 2015). Business models severely affected by digitization range from the musical industry, to e-commerce (Nylén & Holmstrom, 2015) and e-book (Yoo et al., 2012) to mention a few. Another business phenomenon that digitization is impacting is the servitization of the offer (Gobble, 2018). Servitized offers, initially product-centric, are increasingly adding digital services toward a more service-oriented offer (Ayala, Gerstlberger, & Frank, 2019; Lerch & Gotsch, 2015). This impact is so important that digitization is seen as an essential enabler of servitized business models (Ayala, Paslauski, Ghezzi, & Frank, 2017; Gobble, 2018; Kowalkowski, Kindström, & Gebauer, 2013), since servitization nearly always requires digitization and is often supported by it (Gobble, 2018).

One of these digitization-based innovations for servitized offers are Digitalized Product-Service Systems (hereafter DPSS) (Lerch & Gotsch, 2015), also known as remote monitoring technologies (Grubic, 2018), smart connected products (Porter & Heppelmann, 2015) or smart product service systems. Examples of digitalized innovation outcomes through DPSS offers are jet engines that collect data from

different aspects of engine performance (pressure, temperature, oil, etc.) allowing a business model that guarantees performance, and reducing risks by leveraging the use of the data collected (Grubic, 2018). Another example is a scooter sharing service developed by Piaggio that relies on digital technologies to enable a business model that charges the customer for the actual usage of the motorcycle based on GPS data and other data such as acceleration, fuel consumption and braking intensity (Ardolino et al., 2017).

Alternatively, digital technologies could also be used during the process of innovation to facilitate the effective orchestration and collaboration required for DPSS development and delivery (Pagoropoulos et al., 2017). This includes a broad range of digital tools such as PLM, data mining, decision support systems, virtual simulation, social media, digital collaborative working systems for making innovation possible (Lerch & Gotsch, 2015; Nambisan, 2013).

While the literature shows increasing interest in digitally enabled servitization (Kowalkowski et al., 2013), the analysis of digitization barriers is still emerging (Yoo et al., 2012), especially in the context of innovation process and outcome (Nambisan, 2013). Only a few studies reported some barriers encountered from empirical evidences. Examples of barriers for digitization affecting servitization strategies are firms needing to externally recruit personnel for specialized digital roles or the development of new skills and internal capabilities inside the firm and among employees (Coreynen et al., 2015; Nylén & Holmstrom, 2015). Also, the right combination of team skills is necessary, which may be a barrier for digitization in the innovation process (Nylén & Holmstrom, 2015). Barriers for digitization in the innovation outcome are also present such as the uncertainty in the money invested (Coreynen et al., 2015), customers' experiencing unforeseen technical issues (Coreynen et al., 2015), customers' seeking more personal interactions (Paluch, 2014), or even data hacking and privacy concerns (Porter & Heppelmann, 2015; Rymaszewska, Helo, & Gunasekaran, 2017).

Although these studies provide some barriers, they do not provide a detailed picture of the challenge of implementing a digital servitization strategy. Also, few research focus on the digitization of a product-service system offer (Gobble, 2018; Nambisan & Baron, 2013; Nylén & Holmstrom, 2015). Therefore, our study aims to identify the barriers of digitization by distinguishing the two roles of digital technologies in innovation, namely: the use in the innovation process and the use in the innovation outcome. For example DPSS can provide data for product R&D and also

leverage digitization in the final product, as for example an OEM that uses its digital capabilities to analyze data and improve the process itself (Lerch and Gotsch 2015; Porter and Heppelmann 2015).

2 METHOD

Considering the exploratory nature of the objective that guides this research, we adopted a qualitative approach to collect and analyze data. Therefore, two focus groups were conducted using direct procedures (i.e. participants were aware of what was being studied) to identify barriers to the digitization of the innovation process and outcome for DPSS, following the suggestions of (Malhotra, 2010). Focus group is a technique that builds on group discussions to provide insights and are normally conducted with the participation of 6 to 12 individuals who are similar in some aspect and which can provide rich information on the subject studied (Asbury, 1995).

Since consultants' and researchers' view could differ from that of managers and practitioners, we decided to conduct two separate focus groups, each focused on one of the two views, as recommended by (Asbury, 1995; Malhotra, 2010). The aim of this procedure was twofold: first, collecting data from the two separate sources provided us with complementary information, that is, information overlooked from one group could arise in the other group, which helped provide a more comprehensive amount of data; second, given the different views from both groups of respondents, we were able to compare the different perspectives and their perception of the strength of impact of barriers.

2.1 DATA COLLECTION

The two focus groups were conducted separately and lasted in average 1 hour each to identify barriers from actors with a good experience in digital servitization. The first focus group was organized during a one-day conference on innovation practices mainly dedicated to consultants and researchers. It was conducted in September 2018 in France. 11 participants took part in the focus group, being mostly consultants and researchers. In their majority, participants were from consulting companies, university or higher education institutions (HEI), and innovation centers.

The second focus group was conducted in October 2018 also in France during the annual Digital Technologies exhibition. This workshop focused on the perception of industrial actors, and thus, 9 managers from firms participated. Participants were mostly from metal-mechanic and automation, watches and sporting goods, and energy sectors. Their positions were

mostly related to Information Technology, and Research and Development. **Table 2** presents the characteristics of the participants from the focus groups.

Table 2 - Characteristics of participants

Focus Group 1 – Consultants and Researchers		**Focus Group 2 – Managers**	
Sector	**n**	**Sector**	**n**
Consulting company	5	Metal-mechanic/automation	3
University/HEI	2	Watches and sporting goods	2
Innovation center	2	Energy	2
Others	2	Other	2
Positions/Department	**n**	**Positions/Department**	**n**
Consultant	7	IT	3
Researcher	2	R&D	2
Others	2	Others	3

During both focus groups, participants underwent a brief presentation (15-minute slideshow) introducing the concept of digital technologies, and how they can be used as part of the innovation outcome and in the innovation process for DPSS. Although all the participants were aware of the concept and had previous contact with it in academic settings and practical environments, such as their firms, this step aimed to level the knowledge on the issue among participants and to avoid any misconception about the topic. To increase tangibility of the concept presented, we provided a few practical examples of how digital technologies can be used in the innovation process and in the innovation outcome.

After the concepts were presented, participants were first asked to indicate the barriers that firms encounter when they introduce digital technologies in their innovation process. Sticky notes were provided so participants could individually write the barriers and attach them to a board. The moderator of the focus group clustered barriers based on their qualitative similarity in short open discussions with the participants, and, clusters were named accordingly. This step was used to gain collective insights on the barriers indicated by participants and how they impacted firms.

In line with the research objective, researchers provided an online collaborative platform where participants were asked to rank the clusters of barriers based on their impact strength from first (highest impact) to last (least impact). This step was done individually, and it aimed to, ultimately, provide researchers with a rank of the most important barriers. As the final step, participants were debriefed, and a short discussion of the results was conducted. The same process was repeated for the barriers to the digitization of the offer.

2.2 DATA ANALYSIS

Data collected in the two focus groups were exported in spreadsheets and analyzed considering the theoretical background presented in Section 1. Therefore, responses were compiled and frequency of ranking positions of each barrier was analyzed. To reach a final ranking of barriers, scores were calculated based on the frequency of each barrier on each position of the rank. Therefore, every time a barrier was ranked first, it was assigned 10 points; every time it was ranked second, it was assigned 9 points, and so on. This also helped balance the scores by not neglecting barriers ranked in the last positions, since they were also assigned scores, although to a lesser degree.

Finally, scores were calculated, and barriers were ranked from highest (most impactful) to lowest. The rankings were used to analyze data and propose findings, which are presented and discussed in Section 3. Analysis of findings considered specially and the difference in barriers perceived in the innovation process and those in the innovation outcome of PSS. Additionally, we analyze the differences in the views of consultants and researchers, and managers.

3. RESULTS AND DISCUSSION

In this section, we present the barriers mapped during the focus groups to identify what hinders digitization during the innovation process and in the innovation outcome. We found that the barriers mapped can be divided into three major types: strategic, operational, and human resource barriers. Strategic barriers are related to strategic issues, such as the marketing of digitalized solutions, the ecosystem necessary for them to work, and the aspects related to risks, transparency of information, and trust. Operational barriers comprise the aspects involved in putting the digital technology to work in the process or in the outcome. Operational barriers involve functional aspects of the digitization, such as the financial elements, data security, necessary resources and infrastructure, and how to use the DT, among other barriers. Finally, human resource barriers address the existing relationship between the DT and its impact on work organization. These barriers involve training, the necessary competences for DT, how employees view DT, and the resistance to change. **Table 3** summarizes the full set of barriers mapped and their definition.

Table 3 - Barriers and description

Barrier	Definition
Strategic	
Customer need	Understanding customer needs for digitization is difficult and requires a close contact with the customer.
Ecosystem	Barrier related to being in an ecosystem with partners that are prepared for digitization and integrated solutions.
Governance	Decision-making issues such as the fear of losing power.
Market acceptance	Barrier related to the uncertainty of a service-oriented business model that may not meet market needs
Market entrance	Barrier related to new market channels, technologies that are easily copied by competitors, and time-to-market speed.
Offer	Addresses the strategic and planned introduction of DT.
Risk taking	Barrier related to the risks involved in digitization.
Short-term vision	Short vision of the future due to a focus on daily activities, neglecting long-term strategic potential of digitization, thus not prioritizing DT.
Transparency	Transparency barriers comprise the fear of losing control of the information by exchanging/opening it
Trust	Digitization includes trusting suppliers and customers (and being trusted by them) with confidential data.
Operational	
Data security	Data security barriers are related to the fear of hacking, lack of confidentiality, reliability, and data protection.
Financial	Related to the costs and investments of digitization structure, the difficulty in quantifying return of investment
Industrial context	Company context and industrialization degree require adaptations and different starting points for digitization.
Life cycle	Barrier related to the maintenance and support of the DT.
Obsolescence	DT tend to become obsolete after a short period of time.
Organization	The lack of operational processes that allow digitization and the time necessary for DT implementation
Resource	Addresses the lack of appropriate tools, resources and infrastructure necessary for digitization.
Usage	Includes compatibility with current technologies, difficulty in using DT, and how mobile and cloud-based DT are.
Human Resource	
Competences	Competences and knowledge for digitization, such as: training, focus on hardware, digital maturity, and language
Human	Fear of machines replacing humans and new work relations
Resistance to change	Barrier related to the established mindset, the need for flexibility, and the redesign of processes and methods.
Training	Barriers related to the lack of specialized training on DT.

3.1 PROCESS BARRIERS

The ranking of the barriers for digitization of the process are presented in **Table 4**. As the results show, mainly, Human resources-related barriers are mentioned in this stage of innovation. Human resource aspects involve mostly the competences necessary for digitization, the human aspect of job replacement for machines and robots, and the resistance to change due to ongoing mindset. This finding demonstrates a great concern of managers and researchers for the aspects related to employees' relation to digitization in the process. However, for the

Operational barriers, Financial was the most cited obstacle. It is also worth noting that strategic barriers are not ranked with such importance as the other barriers, since the first strategic barrier (e.g. Short-term vision) appears only after five barriers from the other two constructs. This finding shows a more practical concern of how digitization can be implemented in practical terms, such as, for example, financial, data security, usage, and organizational instead of strategic in this stage of innovation through digitization.

Finding 1 - Process barriers are more focused on operational and human resource aspects of digitization.

Table 4 - Top ranked process barriers and their types

Barrier	Points	Type
Financial	126	Operational
Competences	104	Human Resource
Resistance to change	94	Human Resource
Human	72	Human Resource
Data security	64	Operational
Short-term vision	59	Strategic
Training	50	Human Resource
Risk taking	41	Strategic
Governance	38	Strategic
Usage	37	Operational
Transparency	35	Strategic
Industrial context	23	Operational
Organization	22	Operational

3.2. OUTCOME BARRIERS

As presented in **Table 5**, barriers of digitization in the outcome mainly focus on strategic aspects (such as Market Acceptance, Vision and Market Entrance) and operational barriers (such as Financial and Data Security). The most mentioned Human Resource barrier was Resistance to Change, which ranked sixth.

Finding 2 - Outcome barriers are more related to strategic and operational aspects of digitization of the servitized offer.

Table 5 - Top ranked outcome barriers and their types

Barrier	Points	Type
Market Acceptance	121	Strategic
Financial	98	Operational
Short-term vision	87	Strategic
Data security	73	Operational
Market entrance	63	Strategic
Resistance to change	50	Human Resource
Usage	45	Operational
Life cycle	45	Operational
Ecosystem	44	Strategic
Obsolescence	42	Operational
Competences	41	Human Resource
Trust	40	Strategic
Transparency	34	Strategic
Risk taking	33	Strategic
Customer need	29	Strategic
Offer	28	Strategic
Resource	15	Operational

Also, as the results presented in **Table 5**, managers and consultants and researchers perceive more barriers in the digitalized outcome in comparison to those of the process. This fact may be explained by the uncertainty involved in the delivery of such offer, such as the necessary market acceptance and entrance, or the resistance of customers to change as well as the difficulties found in its use.

Finding 3 - Consultants and researchers and managers perceive more barriers in the digitization of the outcome than the digitization of the process.

3.3 ANALYSIS OF PERCEPTIONS

The difference between the barriers perceived by consultants and researchers and manager were also analyzed, the results are presented in **Table 6** and **Table 7**. Consultants and researchers identify different barriers than managers, whether in the innovation process or in the outcome. This is due to several factors but, as seen in the results of the focus groups, managers have an excessive focus on operational aspects, given that they are responsible for day-by-day activities generating an immediatism in their view of barriers, such as Human, Resistance to Change, Training and Financial in the process side; and Competences, Trust and Risk Taking in the outcome side. Whereas consultants tend to see more strategic barriers such as Market Acceptance,

Short-term Vision and Resistance to change on the outcome side, and Competences and Short-term vision on the process side.

Finding 4 - Managers have a short-term view oriented to operationalization aspects of digitization whereas consultants have a long-term view oriented to strategic aspects of digitization.

Table 6 - Ranking of digitization barriers for the innovation process

Rank	Consultants and Researchers	Score	Managers	Score
1st	Financial	77	Human	72
2nd	Competences	74	Resistance to change	66
3rd	Short-term vision	59	Training	50
4th	Data security	43	Financial	49
5th	Usage	37	Risk taking	41
6th	Transparency	35	Governance	38
7th	Organization	22	Competences	30
8th	Resistance to change	28	Industrial context	23
9th	-	-	Data security	21

Table 7 - Ranking of digitization barriers for innovation outcome

Rank	Consultants and Researchers	Score	Managers	Score
1st	Market Acceptance	121	Ecosystem	44
2nd	Short-term vision	87	Competences	41
3rd	Financial	78	Trust	40
4th	Resistance to change	50	Risk Taking	33
5th	Market Entrance	48	Data security	33
6th	Life cycle	45	Customer need	29
7th	Usage	45	Offer	28
8th	Obsolescence	42	Financial	20
9th	Data security	40	Market Entrance	15
10th	Transparency	34	Resource	15

We found that financial barriers are among the most important barriers for both digitization in the process and in the outcome. Regarding financial aspects, literature has not reached a consensus as to their impact. While (Yoo et al., 2012) claims that financial barriers are nowadays not a notable barrier since technology, chips and memory have decreased in price, (Lokuge, Sedera, Grover, Dongming, & Xu, 2018) states that this barrier highly affects successful digital innovations.

Specifically, we found that consultants and researchers rate financial barriers as more important than managers do, as **Table 5** and **Table 7** show. According to (Lokuge et al., 2018),

the financial barrier can be diminished with a flexibilization of the application of resources by the firms.

Finding 5 - Financial barriers are among the most important barriers for digitization.

Another finding from the analysis shows that data security is an important barrier. Such finding is a frequently mentioned problem in digitization (see (Paluch 2014; Porter and Heppelmann 2015; Rymaszewska et al. 2017)). Since, although digitization provides new uses and possibilities, both researched groups agree that the risks to data are still a problem. In this sense, as presented in the results, it is possible to see that managers are more concerned with data in the digitalized innovation outcome, whereas consultants and researchers identify such barrier to a higher extent in the innovation process.

Finding 6 - Data security is a major barrier to digitization.

The development of digitalized offers may present challenges related to the ecosystem. This barrier, according to (Herterich, Uebernickel, & Brenner, 2016; Lokuge et al., 2018) is characterized as maintaining relationships with external stakeholders such as vendors, consultants and even customers. However, developing partnerships and exchanging information can be very hard and time consuming (Ayala et al., 2017; Paslauski, Ayala, Tortorella, & Frank, 2016), which explains such barrier. Also, decisions such as make or buy hinder the development of digitalized innovation outcomes since several factors must be considered, such as collaboration in some fronts and competition on others (Porter and Heppelmann 2015; Yoo, Henfridsson, and Lyytinen 2010).

Finding 7 - To managers, barriers related to the ecosystem are the main obstacle to digitalized innovation outcomes.

4. CONCLUSION

This article provides new insights both for managers and researchers. We showed an overview of the barriers found in the innovation process and outcome, which allows an understanding of the obstacles found when digital servitization is implemented. In this sense our study identified that the respondents identify less process barriers, which are more focused on operational and human-resource aspects. Whereas in the digitally servitized outcome more barriers are perceived, and the focus lies on operational and strategic barriers. Such findings allow decision-makers to better understand the variables that might difficult a successful use of digital tools and digitization in innovation, more specifically these decision-makers can identify

the barriers in the two innovation stages, namely: process and outcome (Pagoropoulos et al., 2017) and leverage such information in each moment of innovation to develop solutions to overcome such barriers.

Also, we identified that, in general, managers are more concerned with operational aspects of innovation whereas consultants and researchers mainly focus on strategic aspects, which demonstrates that literature and practice still differ in their understanding of DT barriers.

Finally, we suggest future research to employ efforts on digitalized innovation, especially in the outcome stage, as according to respondents, this stage faces more barriers, due to the risks involved and the newness of the theme, such as those faced in the development and offer of digitalized product-service systems (Coreynen et al., 2015).

Acknowledgements

The authors thank the Brazilian National Council for Scientific and Technological Development (CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico) (Process n.205844/2015-6), the Research Council of the State of Rio Grande do Sul (FAPERGS, Fundação de Amparo à Pesquisa do estado do Rio Grande do Sul) (process n.17/2551-0001) and the Research Coordination of the Brazilian Ministry of Education (CAPES), and the French Ministry of Education for the financial support received to conduct this research.

REFERENCES

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Ruggeri, C., Ardolino, M., … Gaiardelli, P. (2017). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *7543*(May), 0. https://doi.org/10.1080/00207543.2017.1324224

Asbury, J.-E. (1995). Overview of Focus Group Research. *Qualitative Health Research*, *5*(4), 414–420. https://doi.org/10.1177/104973239500500402

Ayala, N. F., Gerstlberger, W., & Frank, A. G. (2019). Managing servitization in product companies: the moderating role of service suppliers. *International Journal of Operations and Production Management*, *39*(1), 43–74. https://doi.org/10.1108/IJOPM-08-2017-0484

Ayala, N. F., Paslauski, C. A., Ghezzi, A., & Frank, A. G. (2017). Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *International Journal of Production Economics*, *193*(August 2016), 538–553. https://doi.org/10.1016/j.ijpe.2017.08.019

Coreynen, W., Matthyssens, P., & Van Bockhaven, W. (2015). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Industrial Marketing Management*, *60*, 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*(December 2017), 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

Ferreira, J. J. M., Fernandes, C. I., & Ferreira, F. A. F. (2018). To be or not to be digital, that is the question: Firm innovation and performance. *Journal of Business Research*, (June), 1–8. https://doi.org/10.1016/j.jbusres.2018.11.013

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*(January), 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*(January), 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Gobble, M. M. (2018). Digitization, Digitization, and Innovation. *Research-Technology Management*, *61*(4), 56–59. https://doi.org/10.1080/08956308.2018.1471280

Grubic, T. (2018). Remote monitoring technology and servitization: Exploring the relationship. *Computers in Industry*, *100*, 148–158. https://doi.org/10.1016/j.compind.2018.05.002

Herterich, M. M., Uebernickel, F., & Brenner, W. (2016). Stepwise Evolution of Capabilities for Harnessing Digital Data Streams in Data-Driven Industrial Services. *MIS Quarterly Executive*, *15*(4), 297–318. Retrieved from http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=bth%7B&%7DAN=120565633%7B&%7Dsite=ehost-live

Kowalkowski, C., Kindström, D., & Gebauer, H. (2013). ICT as a catalyst for service business orientation. *Journal of Business & Industrial Marketing*, *28*(6), 506–513. https://doi.org/10.1108/JBIM-04-2013-0096

Lerch, C., & Gotsch, M. (2015). Digitalized Product-Service Systems in Manufacturing Firms: A Case Study Analysis. *Research-Technology Management*, *58*(5), 45–52.

https://doi.org/10.5437/08956308X5805357
Lokuge, S., Sedera, D., Grover, V., Dongming, X., & Xu, D. (2018). Organizational readiness for digital innovation: Development and empirical calibration of a construct. *Information & Management*, (September). https://doi.org/https://doi.org/10.1016/j.im.2018.09.001
Malhotra, N. K. (2010). *Marketing Research: An applied orientation*. *Prentice Hall* (6th ed.).
Nambisan, S. (2013). Information Technology and Product/Service Innovation: A Brief Assessment and Some Suggestions for Future Research. *Journal of the Association for Information Systems*, *14*(4), 215–226. https://doi.org/10.17705/1jais.00327
Nambisan, S., & Baron, R. A. (2013). Entrepreneurship in innovation ecosystems: Entrepreneurs' self-regulatory processes and their implications for new venture success. *Entrepreneurship: Theory and Practice*, *37*(5), 1071–1097. https://doi.org/10.1111/j.1540-6520.2012.00519.x
Nylén, D., & Holmstrom, J. (2015). Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Business Horizons*, *58*(1), 57–67. https://doi.org/10.1016/j.bushor.2014.09.001
Pagoropoulos, A., Maier, A., & McAloone, T. C. (2017). Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry. *Journal of Cleaner Production*, *166*, 369–380. https://doi.org/10.1016/j.jclepro.2017.08.019
Paluch, S. (2014). Customer expectations of remote maintenance services in the medical equipment industry. *Journal of Service Management*, *25*(5), 639–653. https://doi.org/10.1108/JOSM-07-2013-0195
Paslauski, C. A., Ayala, N. F., Tortorella, G. L., & Frank, A. G. (2016). The Last Border for Servitization. *Procedia CIRP*, *47*, 394–399. https://doi.org/10.1016/j.procir.2016.03.056
Porter, M. E., & Heppelmann, J. E. (2015). How Smart, Connected Products Are Transforming Competition. *Harvard Business Review*, *1*(OCTOBER), 7250–7257. https://doi.org/10.1017/CBO9781107415324.004
Porter, M., & Heppelmann, J. (2015). How smart, conected products are transforming companies. *Harvard Business Review*, (October). https://doi.org/10.1017/CBO9781107415324.004
Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics*, *192*, 92–105. https://doi.org/https://doi.org/10.1016/j.ijpe.2017.02.016
Yoo, Y., Boland, R. J., Lyytinen, K., & Majchrzak, A. (2012). Organizing for Innovation in the Digitized World. *Organization Science*, *23*(5), 1398–1408. https://doi.org/10.1287/orsc.1120.0771
Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). The new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, *21*(4), 724–735. https://doi.org/10.1287/isre.1100.0322

3 ARTICLE 2 – DIGITAL PRODUCT-SERVICE SYSTEMS: A LITERATURE REVIEW ON THE CONVERGENCE BETWEEN SERVITIZATION AND DIGITIZATION

Abstract: Servitization and digitization have been two concepts of increasing interest for both academia and practitioners. The combination of both concepts in product-centric firms results in the offer of digital product-service systems (DPSS). However, since this is still an emerging concept in the traditional product-service system literature, there is a lack of clear understanding regarding how DPSS can be classified and what specific types of DPSS product firms can adopt. Therefore, through a systematic literature review with 59 articles, this article aims to propose a classification framework for DPSS. The proposed framework organizes DPSS regarding the capabilities needed and the servitization strategies adopted. Our results show that the DPSS offer can be divided into three levels: 'Basic DPSS' is a more reactive, human dependent level, in which data is used for monitoring purposes. "Intermediary DPSS' focuses on data analysis to improve product availability. 'Advanced DPSS' provides result-oriented business model leveraging technological capabilities. We show what are the increasing digital capabilities necessary for each level of DPSS and discuss implications for the digital transformation of product firms.

Keywords: Digitization; Servitization; Digital Transformation; Product-Service Systems

1. INTRODUCTION

Servitization has gained attention over the last decades as one of the product and operations strategies from product firms to achieve competitive advantage (Ayala, Gerstlberger, & Frank, 2019; Coreynen, Matthyssens, & Van Bockhaven, 2015). The product-oriented[1] servitization consists in companies adding complementary services to their product offer or transforming the product offer itself into a service offer to deliver more value to the customer (Vandermerwe and Rada, 1988; Baines et. al, 2013; Reim, Parida, Örtqvist, 2015). The servitization concept is based on a demand-pull trend (Frank, Mendes, Ayala, & Ghezzi, 2019) which focuses on delivering value instead of necessarily the ownership of a product (Reim, Parida, & Örtqvist, 2015). Some authors named 'Product Service-Systems' (PSS) to the resulting bundle of product and services of this strategy (Ayala, Paslauski, Ghezzi, & Frank, 2017; Baines et al., 2007).

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 to make the product autonomous (Lerch & Gotsch, 2015; Rönnberg Sjödin, Parida, & Kohtamäki, 2016). In this sense, digital capabilities can improve industry's competitiveness (Porter & Heppelmann, 2014b) through improvements and the provision of

[1] We differentiate this from customer-oriented servitization, which is a broader category used by some authors (e.g. (Visnjic, Ringov, & Arts, 2019)) to describe a type of services offered by product firms which does not have direct connection to the product offer (e.g. financial services for customers).

data to increase customer relationships (Coreynen et al., 2015). Digitization is also responsible for developing and delivering smarter products (Nambisan, 2013; Porter & Heppelmann, 2015). Smart Products are able to monitor, control, optimize and even operate autonomously in order to better address customers' needs with less resources and better customization (Porter & Heppelmann, 2015). These products range from intelligent cleaning robots (Porter & Heppelmann, 2015) to sensors that analyze in real-time the performance of trains, cranes, cars and whole fleets (Grubic, 2018; Porter & Heppelmann, 2015; Rymaszewska, Helo, & Gunasekaran, 2017). These digitally-enabled products enable a more ubiquitous monitoring of the use, more individualized offers (Nylén & Holmstrom, 2015), and also become the channel of data and information to foster business feedback for internal improvements (Frank et al., 2019).

The interaction between servitization and digitization is very strong, since technology acts as facilitators, and is essential in the servitization process (Gago & Rubalcaba, 2007; Grubic, 2018).The convergence of servitization and digitization strategies results in the provision of digital services embedded into physical products (Holmström & Partanen, 2014; Frank et al., 2019b), namely digital product-service systems (DPSS) (Lerch & Gotsch, 2015). This variation of the 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, 2015c; Rymaszewska, Helo, & Gunasekaran, 2017; Vinet & Zhedanov, 2011). The digital technologies are here is understood as any platform, software or hardware, that allows a connection to the product/service independently of its location (Lerch & Gotsch, 2015c; Vinet & Zhedanov, 2011). 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 guarantees contracts (Lerch & Gotsch, 2015). These factors show that digital technologies are a key factor for the provision of high value-added services (Rönnberg Sjödin et al., 2016), and also to provide potential gains in operational efficiency (Coreynen et al., 2015), improving companies' competitiveness (Porter & Heppelmann, 2014).

DPSS concept follows a move of industries towards a PSS offer more focused on data and information, responsiveness and increased value co-creation (Ardolino et al., 2017; Belvedere et al., 2013; Rymaszewska et al., 2017). However, even when several industrial cases of DPSS are reported in the literature, they are still mixed with the more general servitization literature as well as with the smart product literature. In this sense, from a theoretical perspective, there is a need of framing the different ways DPSS can be offered, so that both, scholars and practitioners can better understand how to exploit the potential of this new approach (Frank et al., 2019). From the academic perspective, this can help to better understand different ways servitization is configured in product firms, while from the practical perspective, this can help to better choose the DPSS solution the company should offer and the form the company's business model has to be configured to it (Frank et al., 2019b). Thus, the aim of this study is to address this gap by answering the following questions: *what are the different DPSS types that product firms can offer? What are the digital capabilities necessary to offer these DPSS types? and how traditional, product-centric, servitization levels relate to DPSS levels.*

Through the research questions proposed, this article aims to consolidate the DPSS understanding by means of a theoretical framework that explains the relationship between different DPSS types and the required digital capabilities to offer each level. Additionally, we propose how DPSS levels are related to the proposed servitization levels as a means to provide

an understanding on how the two concepts interface, as well as, to show how one literature can benefit from the findings of the other. We develop our framework based on a systematic literature review which resulted in 59 final papers on the DPSS field. We analyzed and contrasted these works to propose a consolidated classification for DPSS and the necessary digital capabilities to offer each level. Also, we analyze how each DPSS level relates to the product-centric servitization literature. As a main contribution, the framework provides a common understanding of the DPSS among different servitization streams, which can serve for comparison, evaluation and further understanding of this field. We also show how product firms can implement these different DPSS types, by considering the capabilities and servitization strategies necessary for them.

2. SERVITIZATION AND DIGITIZATION: FROM PSS TO DPSS

From the initial definitions proposed by Vandermerwe and Rada (1988) to today's well stablished background on this field, several studies have investigated the servitization phenomena, i.e. manufacturing firms that add services to their products with the objective of provide more value to their customers. In this sense, we understand that companies can follow a direct path from pure product to pure services such as the case of IBM (Beuren, Gomes Ferreira, & Cauchick Miguel, 2013). In this approach, Tukker (2004) proposes three classifications for the offer, namely: product-oriented, use-oriented and result-oriented. In this classification, the product-oriented classification refers to services that are an addition to the products acquired, such as maintenance. Whereas in the use-oriented level, the use of the product is offered, instead of the product sale, such as services of sharing or leasing. Finally, the result-oriented level is the sale of the result, independent of the means or product, such as the sale of washed clothes instead of washing machines. However, our focus relies in the segment of manufacturing firms that aim to increase their service offer, without, however, fully detaching the product of their PSS offering, due to the DPSS necessity of integrating the product features with service aspects and digital architectures to deliver value (Lerch & Gotsch, 2015).

In this context of servitization for manufacturing companies, according to Cusumano et al. (2015) companies can define three types of services that complement their product offer in a PSS solution, divided into (i) smoothing, (ii) adapting and (iii) substituting services. The first type, smoothing services, focus on facilitating the use or purchase of the product, such as financing, warranty, training and support. The second type, adapting services, focus on expanding the functionalities of the product with new uses or adapting the product to novel conditions, enabled by customizations, by consultancy services that introduces new uses to the customer or by the offering of a complete solution that bundles tailored product and services. Finally, substituting services are services that replace the purchase of the product itself, such as selling turbine usage instead of the actual engine, which is the case of Rolls Royce "Power by the Hour" program. Such classification focuses on product manufacturing companies that see in servitization a means to furtherly deliver value through added services, as proposed in the DPSS approach.

As earlier seen, the merge of ICTs and PSS, the DPSS delivers value through digital technologies such as the Internet of Things (IoT), Cloud Computing, Big Data and Analytics which enable the development of capabilities that allow the delivery of DPSS, such as user and/or 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), smart watches (Kim & Shin, 2015; Mani & Chouk, 2017) and health trackers (Valencia, Mugge, Schoormans, & Schifferstein, 2015); and on the industrial side with more intelligent machines, such as enameling lines with remote services, maintenance, and repair; machine tools with technical support, upgrade and retrofit based on the data provided by the machine's operation or even whole production lines (Lerch & Gotsch, 2015; Rymaszewska et al., 2017).

However, even when ICTs are clearly stated as enablers of servitization, the addition of ICTs toward the digital servitization of manufacturing is a new research stream that is challenging companies (Grubic, 2018). In this sense, while servitization subject is currently a stablished field (Kowalkowski, Gebauer, & Oliva, 2017), perspectives on the digital servitization field are still needed (Grubic, 2018). Because of this, our aim is to shed light to this phenomenon by organizing the existing knowledge and connecting servitization and digitization concepts towards a clear understanding of DPSS.

3. RESEARCH METHOD

We conducted a systematic literature review based on the literature gaps on DPSS categorization and the capabilities to delivering different levels of DPSS. 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, Denyer, & Smart, 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 are referred to by synonymic terms. This is the case of the DPSS research field, which resides next to such topics as Product-Service System and digitization literature. Additionally, research papers are published in several journals, using synonyms such as smart products (Porter & Heppelmann, 2015), digital servitization (Vendrell-Herrero, Wilson, & Wilson, 2017), remote services, and integrated solutions (Grubic, 2014).

Also, systematic literature reviews serve the purpose of including articles that are published in a wider range of fields due to transparent steps and unbiased search, increasing the legitimacy of the findings and synthesizing research contributions on a given field. Considering the benefits exposed, we followed the recommendations of Tranfield, Denyer, & Smart (2003) to conduct a systematic literature review, dividing it into three stages: review planning (stage 1), conduction (stage 2), and reporting and dissemination (stage 3). 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 and presented previously. 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.

In Stage 2, we searched both databases with the keyword combinations presented in **Table 8** which also presents the quantity of articles retrieved in each database and search. 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 the English language. Additionally, to ensure that articles addressed the topic at hand, we filtered for articles published in the following areas: business, engineering, and social sciences. Thus, the searches conducted in the

two databases resulted in 1837 retrieved 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.

Table 8- Keyword combinations and quantity of articles retrieved

Remote	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*	Scopus: 274 articles retrieved WoS: 158 articles retrieved
Smart	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*	Scopus: 358 articles retrieved WoS: 239 articles retrieved
Digit*	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*	Scopus: 523 articles retrieved WoS: 272 articles retrieved
		"Smart product"	AND	Capabilit*	Scopus: 9 articles retrieved WoS: 4 articles retrieved

Based on the criteria established, 1204 articles were excluded because they did not address the topic or because they focused on DPSS but not at an industrial level, (e.g. articles that studied smart home devices or e-health DPSS). After this filter was applied, the remaining 124 articles were fully read, and the content-based inclusion criteria were applied. The content-based inclusion criteria were articles should present DPSS capabilities, and examples of DPSS in industrial B2B settings. These criteria were defined in line with the objectives of the article and we were able to better identify them when articles were fully read and catalogued. Thus, 46 articles were accepted and, and 78 were rejected.

We also added 13 articles that are reference in the DPSS field, but they were not retrieved because they were either published in a journal that does not include peer-reviewing processes, or because they journal was not indexed by either database. Finally, a corpus of 59 articles were reviewed in depth in Stage 3, and the results are reported in section 4 of this article. **Figure 4** graphically represents the flow diagram of the steps followed in the systematic literature review. Additionally, Annex A summarizes the bibliometric data of the articles reviewed.

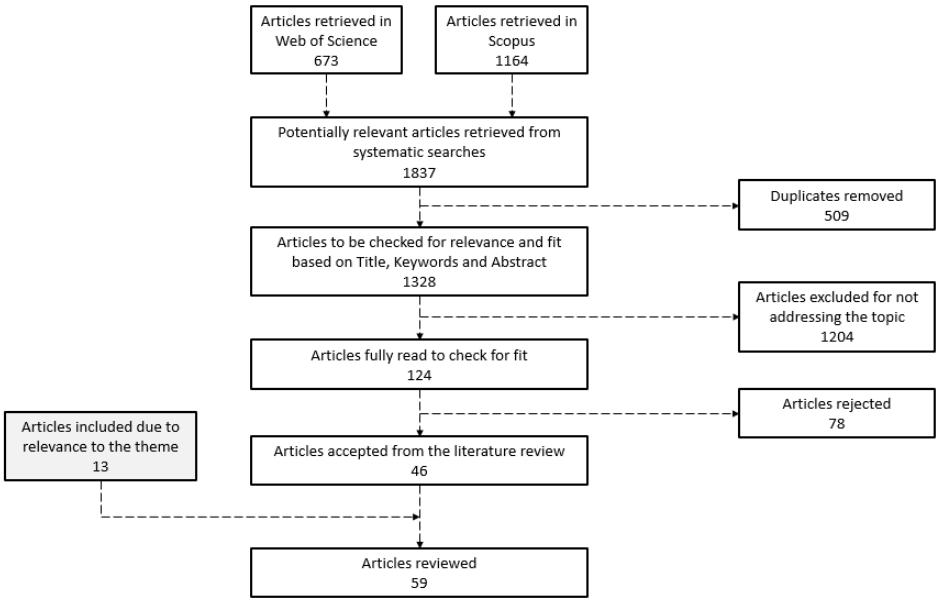


Figure 4 - Flow diagram of the steps for the systematic literature review

With the final set of approved articles, we proceeded to the review process. The results and discussions section bring the analysis of these articles along with our findings.

4. RESULTS AND DISCUSSIONS

4.1 Definition of DPSS

Based on the articles selected, we analyzed how each study defined DPSS, since, there seems to be a wide range of typologies for such offer. **Table 9** - DPSS definitions**Table 9** presents the terms adopted, order from the most mentioned to the least mentioned, and how they define it.

Table 9 - DPSS definitions

Term	Definition	Authors
Remote Monitoring Technology	ICT-enriched products in service delivery	(Grubic, 2014, 2018; Grubic & Jennions, 2017; Grubic & Peppard, 2016)
Digital servitization	Digital services embedded in a physical product.	(Bustinza, Gomes, Vendrell-Herrero, & Tarba, 2018; Holmström, Liotta, & Chaudhuri, 2018; Opazo-Basáez, Vendrell-Herrero, & Bustinza, 2018)
Remote diagnostics systems	Remote diagnostics systems collect, store, and continuously analyze data about the state of machinery and related production processes	(Jonsson, Holmström, & Lyytinen, 2009; Vardar, Gel, & Fowler, 2007)
Smart diagnosis services	Tool for virtual condition monitoring during processing and adaptation based on sensor data	(Caggiano, 2018; Candell, Karim, & Söderholm, 2009)
Smart Services	Preemptive services to identify when a machine is about to fail, customer's supply of consumables is about to be depleted, etc.	(Allmendinger & Lombreglia, 2005; Wuenderlich et al., 2015)
Cloud-assisted remote sensing	Data collection, sharing, remote and real-time access, elastic resource provisioning and pay-as-you-go pricing models.	(Abdelwahab, Hamdaoui, Guizani, & Rayes, 2014)
Data-Driven Industrial Services	Provides a variety of opportunities for data-driven service offerings and enable OEMs to innovate their service businesses	(Herterich, Uebernickel, & Brenner, 2016)
Digital product	Products that are supported by ICTs to improve the delivery of services	(Benssam et al., 2007)
Digitalized Product-Service Systems	PSS incorporated with ICT solutions, creating intelligent, independent operating systems for higher levels of availability and operations optimization	(Lerch & Gotsch, 2015)
Digitization as an enabler for servitization	Digital technologies enable the provision of the servitized offer to deliver higher value	(Coreynen et al., 2015)
e-Diagnostics and e-Maintenance	Provides equipment supplier's experts with the capability to remotely link to factory's equipment through Internet, allowing them to take remote actions.	(Hung, Chen, Ho, & Cheng, 2003)
e-service-driven e-manufacturing mechanism	e-manufacturing is the combination of web-based collaborative manufacturing with e-business process under the participation of customers, suppliers and manufacturers.	(Jiang & Chen, 2007)
ICT-enabled product-service	ICTs enabling the adoption of product-service systems.	(Belvedere et al., 2013)
ICT-enabled services	Use of ICT to add services to their existing offerings in order to create value and achieve sustainable competitive advantage.	(Kowalkowski, Kindström, & Gebauer, 2013)
IoT powered	IT-driven servitization, offering integrated	(Rymaszewska et al., 2017)

servitization	product–service bundles that acknowledges the disruptions brought by IoT.	
Internet-Enabled Calibration Services	Access to measurement and calibration services, such as remote control through the internet.	(Jurčević, Boršić, Malarić, & Hegeduš, 2008)
Multimedia tool support for remote maintenance	Integrated engineering tools created to support the implementation of automation systems utilized to support effective remote maintenance services	(Ong, West, Lee, & Harrison, 2007)
Remote Operation and Monitoring	Software application that enables remote operation and monitoring of an equipment through the Internet.	(Diakostefanis, Nikolaidis, Sampath, & Triantafyllou, 2017)
Remote Services	Technology-mediated service for diagnostics, repair, and maintenance purposes in industries that allow the service provider to access and modify the service.	(Paluch, 2014)
Remote multi-robot monitoring and control system	Characterized by autonomy, reactive behaviors and supervisory control features	(B. Wu, Zhou, & Xi, 2007)
Smart connected manufacturing resources	Manufacturing units with embedded Cyber-Physical Systems and IoT	(Brad, Murar, & Brad, 2017)
Smart, connected products	Intelligent, connected devices embedded in broader (more open-ended) systems (such as networked industrial machines).	(Porter & Heppelmann, 2015)
Smart PSS	PSS enabled by smart technologies (such as programmable, addressable, sensible, communicable, traceable technologies).	(Chowdhury, Haftor, & Pashkevich, 2018)
Service innovation in Data-Rich Environments	Information technology is a key enabler of service innovation by empowering them with capabilities and assets they did not have access to before.	(Troilo, De Luca, & Guenzi, 2017)
No specific term or definition	(Ardolino et al., 2017; Bisio, Garibotto, Grattarola, Lavagetto, & Sciarrone, 2018; Cenamor, Rönnberg Sjödin, & Parida, 2017; Chaâri et al., 2016; Chang, Li, Hung, & Yen, 2013; Chiou, Mookiah, & Kwon, 2009; Condry & Nelson, 2016; Demirkan & Delen, 2013; Du, Liu, Ma, Wu, & Wu, 2018; Gago & Rubalcaba, 2007; Ives, Joaquin A. Rodriguez, & Biagio Palese, 2016; Jitpaiboon, Dobrzykowski, Ragu-Nathan, & Vonderembse, 2013; Kiritsis, 2011; Lenka, Parida, & Wincent, 2017; Liu, Zha, Miao, & Lee, 2005; Marinova, de Ruyter, Huang, Meuter, & Challagalla, 2017; Megliola, Sanguini, & Sesana, 2015; Ness, Swift, Ranasinghe, Xing, & Soebarto, 2015; Okathe, Heydari, Sood, Cole, & El-Khatib, 2016; Ostrom, Parasuraman, Bowen, Patrício, & Voss, 2015; Pagoropoulos, Maier, & McAloone, 2017; Parida, Sjödin, Lenka, & Wincent, 2015; Smith, 2013; Song & Moon, 2017; D. Wu, Terpenny, & Schaefer, 2017; Zaeh, Reinhart, Ostgathe, Geiger, & Lau, 2010; Zhu, Zhao, Tang, & Zhang, 2015)	

As it can be noticed in

, several definitions are used to define a DPSS. Such finding is also reported in the article of Grubic (2014) who identifies that several are the definitions and terminologies in the DPSS field. As **Table 9** summarizes, the most common technological terminology used is digital and remote. Whereas on the product-service perspective, due to the increasing research on PSS, PSS is the most common terminology used. Therefore, the term Digital Product-Service System presents the most suitable terminology for the field despite the pulverized list of terms adopted.

Analyzing all definitions of DPSS in **Table 9**, it is possible to observe that the DPSS concept relies on three basic characteristics: (i) digital technologies (ICT, remote connection, smartness); (ii) a product, through which the service is delivered; and (iii) a service, that can be a wide range of options from simple product monitoring and diagnosis to the product itself as a service. Following this, we define *a DPSS as a product-service system for which its value delivery relies or is supported by digital technologies*.

4.2 DPSS categorization

Regarding the forms that companies can use digital technologies to support their offer of PSS, different criteria are used by authors to categorize DPSS levels. In this sense we identified that DPSS classifications rely on four main factors that can compose its classification: (i) business model, (ii) risk management, (iii) data utilization and (iv) service delivered. The business model is an important topic that characterizes the DPSS. Articles proposing classifications focused on this aspect, identify how the business in monetized (Herterich et al., 2016) and the contracts are set, such as outcome-based contracts (Kowalkowski et al., 2013) or product usage monetization (Cenamor et al., 2017; Herterich et al., 2016). One example is the classification proposed by Herterich et al. (2016) which is grounded on the offering, where in early stages the focus is on transactions, whereas in more advanced stages the value is the outcome not the product itself, such as the support of customer's operations.

Another important aspect addressed in literature is the risk, since DPSS can reduce the risk associated to the offer through technologies such as remote control and monitoring (Lerch & Gotsch, 2015). Risks here encompass the definition proposed by Reim et al. (2015) who propose that risks consist of technical (product breakdowns), behavioral (customers not handling the product carefully) and delivery competence risks (lack of capability to provide the offer). Therefore, the risk responsibility is an important aspect of the DPSS concept definition, and thus, should be considered in its definition. Additionally, the mitigation of risks is understood as one of the three main benefits brought by the DPSS adoption (Grubic, 2018). Usually the risk management is part of the business model, however, due to its centrality in the DPSS offer we opted to analyze this construct separately since it can present differences from an expected risk definition from a given business model, such as an outcome-based business model with the customer being responsible for most of the risk. In this sense we propose this group of analysis aiming to understand who is responsible for the risks on the DPSS operation.

In another perspective, Coreynen et al. (2015) focuses on the data utilization by the companies in order to propose a classification for DPSS. In this sense the classification studies how technologies are used to improve workflow visualization, customer relations management or to radically change customer-provider relations. Such view is also employed by Troilo et al. (2017) in providing a classification by data density processes which categorized the solutions into pattern spotting, real-time decisioning and synergistic exploration. This classification aims to segment the services offered through the type of technology employed to analyze and leverage data to innovative services (Troilo et al., 2017). Monitoring, control, optimization, and autonomy are also data utilization levels used to classify DPSS (Porter & Heppelmann, 2014).

Finally, studies focus their efforts on the services delivered, as a means to classify DPSS. In the study of Lerch and Gotsch (2015), the first level focuses on delivering maintenance and repair services, hence improving the intangible components of the DPSS. In the middle level the services are focused on improving the performance, efficiency, optimizing and saving resources. Whereas in the final level the services affect the manufacturer's innovation activities through the data being used for R&D activities. Customers also benefit activities via upgrades that make DPSS more automated or independent. Coreynen et al. (2017) and Ardolino et al. (2018) (based on Kowalkowski, Windahl, Kindström, & Gebauer (2015)) divide the path of companies in digital servitization strategies according service delivered. Ardolino et al. (2018) studied how digital technologies affected different servitization trajectories in industries, based on three strategic trajectories: (i) availability provider, (ii)

performance provider and (iii) industrializer. Companies becoming an availability provider (i.e. offering a product-service that increases a resource's availability) leverage digital technologies to regulate how customers can access the product and use it. It also tracks consumption patterns for data analysis. Performance providers (companies offering product-services that increase the outcome of a given resource) leverage technologies by using them to simulate use, anticipating customer's needs and determining changes in the equipment or its processes. As for the industrialiser strategy (focused on scaling the infrastructure through standardization of the solutions as a means to reach a larger customer base) uses digital technologies in order to gather data and use it to develop an industrial internet platform.

Therefore, these four aspects of systematization of DPSS taxonomies grounded our analysis. During the systematic literature review, ten papers provided different levels of DPSS categorizations, as presented in **Table** . Authors mainly propose three levels of DPSS that commonly vary from low complexity to high complexity. We analyzed the characteristics of DPSS in each category proposed by the authors and we organized them according to complexity. This complexity classification was conducted based on an analysis of the articles, thus, we identified the characteristic and compared it to the other classifications as a means to understand how the other studies classified it. Thus, if most of the studies understood such characteristic was in the most basic levels, we positioned it in this level. This was done to all the characteristics of business model, risk management, type of service and data utilization, and inconsistencies were discussed among authors. The integrative table with the classifications proposed according to each group is depicted in **Table** .

Table 4: Integrative classification for DPSS

	Authors / Characteristics	Coreynen et al., 2015	Lenka et al., 2017	Herterich et al., 2016	Lerch & Gotsch, 2015	Troilo et al., 2017	Grubic & Jennions, 2017	Grubic, 2018	Kowalkowski et al., 2013	Cenamor et al., 2017	Paluch, 2014
BASIC	**Business model**	Services for companies to maintain control over their operations	Enhanced product functionalities via technology	Product business is the primary focus			Built-in-test before usage		Product utilization report packages	Real-time monitoring of usage data to improve customer's operations	
	Risk Management		Real-time diagnostics of failures	Improved human-centered Maintenance, Repair or Overhaul service operations				Reduction of maintenance costs	Preventive maintenance agreements		24/7 support, but contract not associated to performance
	Type of Service	Maintenance and repair	Monitor, control and identification of optimization opportunities	Remote Monitor product conditions	Remote monitoring and supervision	Remote monitoring	Remote monitoring	Real-time performance data	Remote monitoring and control		Remote monitoring
		Services to support processes	Sense and capture information		Maintenance, repair and spare parts supply						Mobile Connection
	Data utilization	Monitoring	Transmission of information to processing center			Monitoring	Monitoring	Monitoring	Monitoring and Control	Monitoring	Notification; Monitoring

Table 10: Integrative classification for DPSS (continuing)

	Authors / Characteristics	Coreynen et al., 2015	Lenka et al., 2017	Herterich et al., 2016	Lerch & Gotsch, 2015	Troilo et al., 2017	Grubic & Jennions, 2017	Grubic, 2018	Kowalkowski et al., 2013	Cenamor et al., 2017	Paluch, 2014
INTERMEDIARY	**Business model**	Deeper customer relationships Capture customer's needs	Insights into customers' needs	Operational data to leverage engineering of future products	Shorter product development cycles Information for R&D and innovation processes	Collecting data used for new services development		Information on product usage for value creation			Close collaboration with customer
	Risk Management		Improved first-call resolution; Allowing efficiency	Use of product data to perform faster resolutions of on-site problems	Digital communication of failure and cause	Data analysis to solve problems	Fault or failure occurrence	Data supports customers' assets management		Data analysis to support delivery	
	Type of Service	Advice, consulting and workflow optimization	Connection of digitalized products	Better product performance and resources efficiency	Service of optimization of processes and operations	Process optimization with data analysis		Service revenues from customers' product management	Technical consulting, process and optimization	Remote trouble shooting	On-line or on-site support
		Saving on material and energy	Machine connection	Product-complementing services	Comprehensive remote services				Reduced operational costs through process automation	Consulting services	Web-based system for services
		Product training based on Digital Technologies		Service that optimize and complement product operations	Training based on Digital Technologies				Customer training tools	Analyzing and optimizing processes and activities	User's remote access
										Guidance and support	Individual training
	Data utilization	Data processing and interpretation	Data analytics	Selling of data-driven services		Real-time data analytics	Data processing		Information on product performance and usage	Analyzing and optimizing	

Table 11: Integrative classification for DPSS (continuing)

	Authors / Characteristics	Coreynen et al., 2015	Lenka et al., 2017	Herterich et al., 2016	Lerch & Gotsch, 2015	Troilo et al., 2017	Grubic & Jennions, 2017	Grubic, 2018	Kowalkowski et al., 2013	Cenamor et al., 2017	Paluch, 2014
ADVANCED	**Business model**	Result oriented services, guarantying outcomes	Proactive capitalize emerging opportunities leveraged by the data gathered	Monetization according to product usage and the value it generates					Outcome-based	Use-based service	Pay on usage basis
	Risk Management	Risk assessment and mitigation	Mitigation of risks	Better diagnosis allows service provider to become responsible for the whole operation	Availability guarantee; Risk reduction allows lifecycle cost guarantees			Risk Reduction; Improved performance, reliability and availability	Outcome-based contract with dynamic pricing	Use-based service agreements	Better cost estimation
	Type of Service	Customization	Simulation for improved customization	More efficient spare parts management with orders done in advance	Predictive maintenance	Customized value propositions	Determine the type, location or source of a failure	Advanced diagnostic capabilities	Services addressing specific customer's needs	Adaptable and customized offers and tools based on identified customers' needs	Address customer individually
		Field service organization	Better, more organized field services, planned in advance	Better remote fixing software defects							Personalization
	Data utilization		Real-time diagnosis; Predictive insights into the company's operation	Prediction of breakdown, maintenance, repair and overhaul	Prediction of failure	Prediction of future states	Prediction of the remaining useful life of the product				

Grounded on the data above, and the literature analysis, we propose the following definitions and characteristics of each DPSS level.

4.2.1 Basic DPSS

As highlighted in **Table 11**, the Basic DPSS is mainly based on a product-oriented BM, where companies sell their product with services supported by digital technologies, however, these services are mostly reactive and human-dependent (Herterich et al., 2016). In the basic level, services are enabled by fewer technologies that allow sensing, monitoring, control and supervision for remote diagnostics, process supervision, operation history and spare part supply, usually in a preventive maintenance contract (Herterich et al., 2016; Lenka et al., 2017; Lerch & Gotsch, 2015). In this level, data is used only for monitoring and control purposes, triggering human dependent activities, i.e. if a situation or a problem happens, it demands a human action, since it is not automated. Additionally, humans need to define most of the settings and configurations of the product and the services (Lenka et al., 2017). This offer is characterized by a less intense integration between the DPSS provider and the customer company, since such services are the rarely customized. Also, the risk is a responsibility of the customer, since this is a reactive approach.

Companies providing basic DPSS can remotely diagnose failures and better estimate the 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. In this level, companies are able to provide more efficient customer service such as more accurate first-time repair, better maintenance services resulting in lower costs (Paluch, 2014). Another example of event-triggered and general monitoring and control services that fit into this basic DPSS level is the one presented by Rymaszewska et al. (2017) where automatic charts alert factory managers and suppliers when the cooling oil from a transformer is about to boil by transmitting too much power, since such occurrence would shorten its life-time or bring risk to the operation. Companies in this level also deploy sensors inside its machines and hardware parts enabling remote maintenance that result in lower costs for maintenance services, especially for suppliers that are geographically distant from its customers (Lerch & Gotsch, 2015; Paluch, 2014).

4.2.2 Intermediary DPSS

Comparing with the basic level, the intermediary level allows more technologic-complementing services (Lerch & Gotsch, 2015). In this level, service-related offers are conceivable for most DPSS providers due to a higher visibility of product performance through digital technologies. 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). It is also possible to leverage the data gathered to feedback R&D activities, once it can track use patterns and better understand users' needs (Coreynen et al., 2015; Herterich et al., 2016; Lenka et al., 2017; Lerch & Gotsch, 2015). In this sense, given the intense knowledge about customers' operations, manufacturers can also provide consulting

services on how to improve usability, uptime percentage, safety and other aspects, based on the information collected and analyzed (Coreynen et al., 2015). This type of service differs from the basic level once it enables automated decisions, not necessarily dependent of human actions. Such "intelligence" is supported by a real-time automated data analysis, decision-making and machine remote control which allows services such as fleet management, smarter setup and other complementing services that enable an outcome improvement business model that seek to improve the results of the equipment, such as the productivity, efficiency and safety. Therefore, the risk here is shared, due to the necessary interactions between customer and provider.

As exemplified by Rymaszewska et al. (2017), in this level of DPSS, a manufacturer can analyze customer's actions and behaviors to remotely optimize its machines following the key performance indicators, increasing its performance. Another example the cases of a forklift manufacturer that manages and optimizes its customers' fleet and the case of a manufacturer of elevators and escalators that provides a service to manage people flow in large buildings, such as airports, once it can leverage the data provided by its products (Herterich et al., 2016).

4.2.3 Advanced DPSS

Different from prior levels, the advanced DPSS level facilitates result-oriented and device-as-a-service business models due to the provider's risk mitigation supported by the data and the high technology employed (Coreynen et al., 2015; Herterich et al., 2016; Lerch & Gotsch, 2015). This business model is based on the provision of the product and its results as services, in which the provider holds the equipment's ownership. The services in this level are supported by predictive analytics which allows the provider to mitigate risks of breakdowns (Lenka et al., 2017), thus allowing greater reliability and control. Because of this high level of reliability, it is possible to provide availability-based services (Lerch & Gotsch, 2015) or even outcome-based services (Coreynen et al., 2015; Herterich et al., 2016). Service level contracts are enabled by comprehensive remote services such as self-diagnosis, predictive maintenance (Herterich et al., 2016; Lenka et al., 2017; Lerch & Gotsch, 2015), anticipated spare parts orders and simulation of operations (Herterich et al., 2016). The result-oriented business model allows meeting individualized needs with customized solutions, using the real-time collected data (Coreynen et al., 2015; Lenka et al., 2017), which minimizes risks for the provider, which is the responsible for the operation (and consequently the risks). An example of such level is shown by Lerch and Gotsch (2015) in the case of a large machine tool manufacturer that uses digital technologies to leverage long-term advantages in the form of lifecycle cost guarantees and precise availability rates for the different machinery components. Based on the collected data, the manufacturer can consistently determine the full lifecycle cost of its machinery and allow service level contracts with little risk.

Analyzing the characteristics in **Table 10** for each type of DPSS, and grounded on the analysis above, we propose a classification of levels in basic, intermediary and advanced, as it is illustrated in **Figure 5**. These levels must not be seen as building blocks, but as different strategic options made by the DPSS provider.

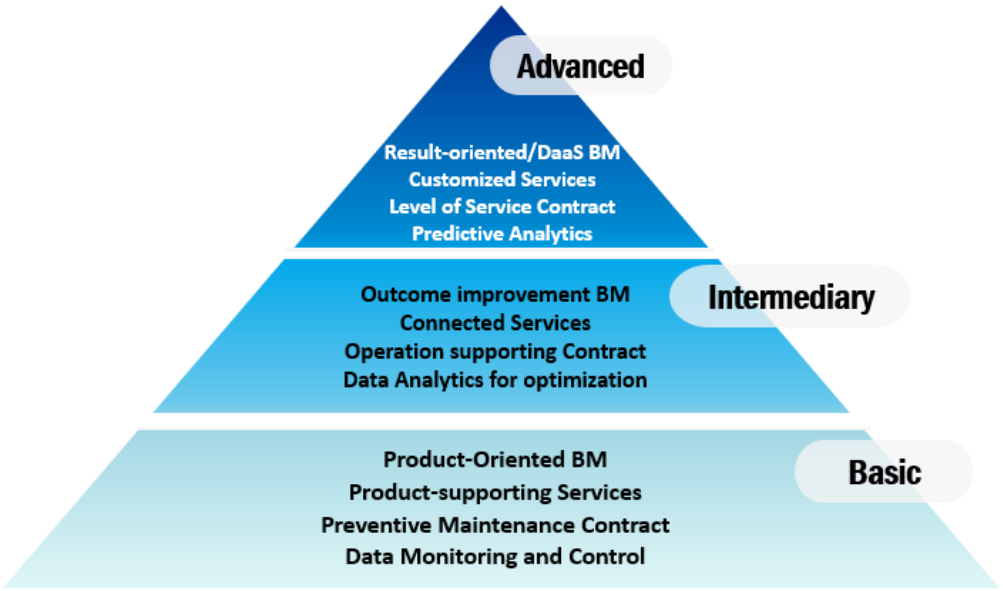


Figure 5 - DPSS levels

4.3 DPSS Capabilities

When servitizing based on digital technologies, companies need to develop digital capabilities in their PSS offer (Ardolino et al., 2017). Digital capabilities' concept derives from the capability definition, being the firm's capacity to deploy resources for a desired end result (Helfat et al., 2009), and digital capabilities as 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 digital technologies such as Cloud Computing, Internet-of-Things (IoT), Predictive Analytics play an active role in PSS value co-creation. The authors provide a framework based on the Data-Information-Knowledge-Wisdom hierarchy, in which each of the technologies play a determinant role. IoT, for instance, acts on the initial level of the hierarchy by providing the data (Ardolino et al., 2017). In such cases, companies can use digital technologies to also reach greater accessibility, through, for example, cloud infrastructure.

Another examples of digital capabilities that support a DPSS are presented by Porter & Heppelmann (2015), namely: monitoring, control, optimization and autonomy. The monitoring capability encompasses technologies such as sensors and external data sources to provide data of the product's condition, environment and usage. Whereas control is made possible through software in the product, or cloud. Optimization builds on the former level's capabilities to enhance product performance and allow predictive diagnostics. Finally, the most advanced capability combines monitoring, control and optimization in order to allow the operation of autonomous products, embedded with self-diagnosis services and enhanced personalization.

Many are the capabilities mentioned in the literature, therefore, recognizing which digital capabilities enable DPSS levels is important for a further understanding of how DPSS could create more value to customers and how companies can provide more accurate DPSS. With this objective, in **Figure 6**, we present an analysis of the capabilities enabled by digitization in PSS according to the results from our systematic literature review. These

capabilities were extracted by studying each example and case study presented in the articles and categorizing according to the DPSS levels early proposed in this article, then we analyzed the capabilities mentioned in the examples. Following the framework proposed in Figure 1, the bars represent the cases that mentioned the specific capability within the DPSS level.

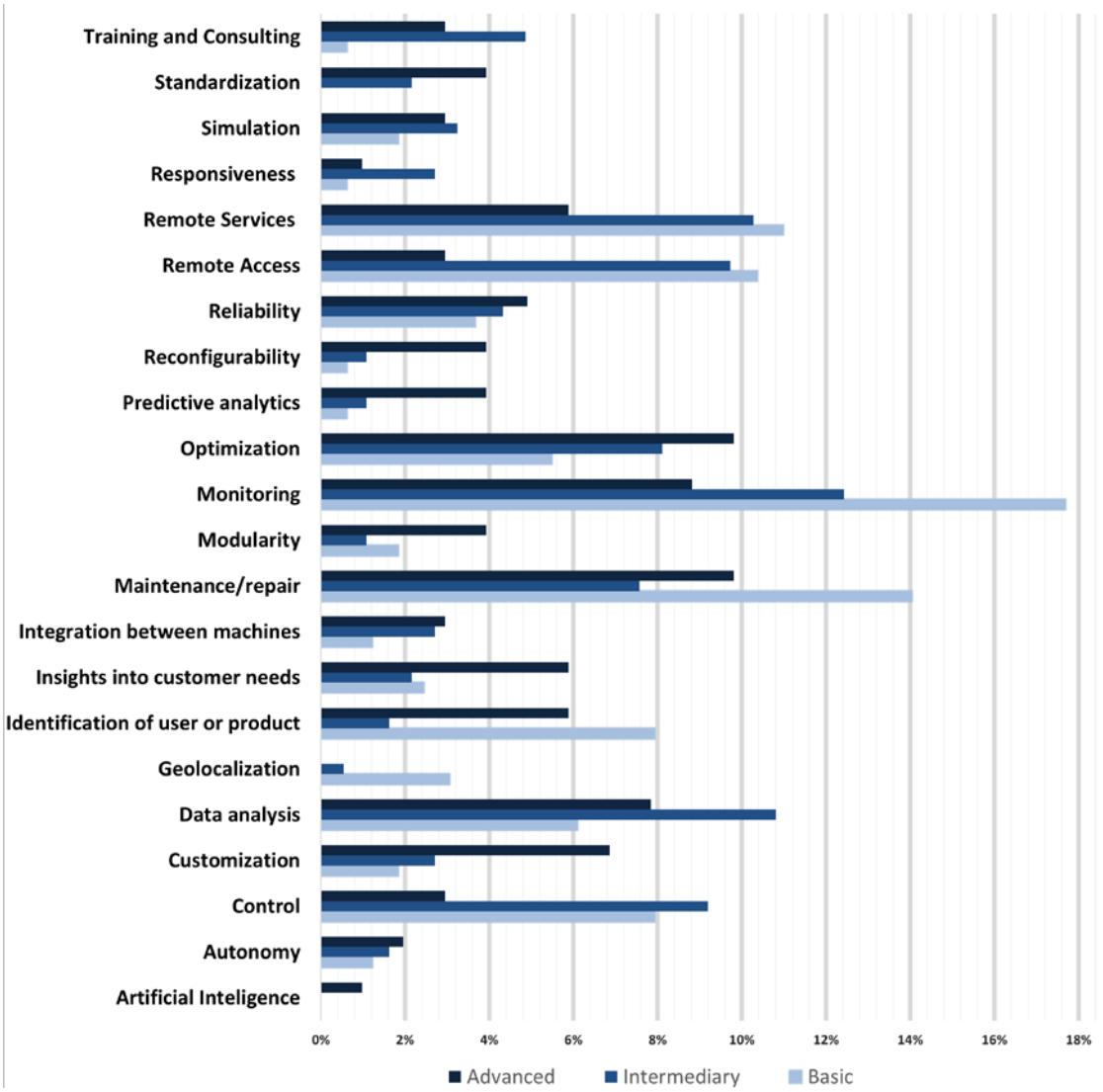


Figure 6 - Digital capabilities by level of DPSS

By presenting which capabilities are more frequently cited in the papers for DPSS, **Figure 6** enables a further understanding of the bundle of capabilities necessary to deliver each level of DPSS. To offer a Basic DPSS, first, providers should develop the capability to remotely access the data generated by the products in customer's site. Also, identification of products is necessary to offer traceability services. Following, provider must have the capabilities of analyzing the collected data to offer remote monitoring, control and optimization services. Alternatively, to be able to offer an Intermediary level of DPSS, providers should add to the digital capabilities of the basic level. training and consulting capabilities to increase reliability of customers processes and help them to extract most value from the DPSS offer.

Remarkably, different from what happened in previous levels, where few capabilities were clearly emphasized against the others, in the Advanced DPSS level there is no clear difference of proportion between the capabilities. Thus, we can conclude that for the offering of Advanced DPSS providers should hold the majority of the digital capabilities to offer a complete value proposition to its customers. These capabilities include most of the necessary capabilities to basic and intermediary levels, but also add 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 to the utilization of data for simulation and predictive analytics.

Notably, the capability to offer maintenance and repair services is highly presented in the three levels of DPSS, what demonstrates that most applications of digital technologies are still highly restricted to this kind of services. However other applications are brought by studies, which demonstrates that there are several uses yet to be discovered in the DPSS field.

4.4 Propositions for DPSS and servitization pathways

As above stated, when observed from a servitization point of view, companies can use service in three different pathways in order to form their PSS package, as proposed by Cusumano et al. (2015): smoothing, adapting and substituting. However, as we demonstrated, when supported by digitization, companies can follow three new alternatives of DPSS, being basic, intermediary and advanced. With the objective of shedding light in the link between both research streams, based on the 60 case studies found in the systematic literature review that presented DPSS with clear servitization pathways, we present three propositions that state the expected synergy and complementarity of these servitized/digitalized business models. The analysis on the relation between DPSS classification and servitization strategies was conducted analyzing the examples given by the studies in cases studies. These examples were analyzed to fit into both, this article's classification and the classification proposed by Cusumano et al. (2015). This analysis was conducted by three researchers to prevent any possible bias.

Figure 7 presents a graphical representation for crossing DPSS levels and Servitization strategies that support to the subsequent discussion of propositions.

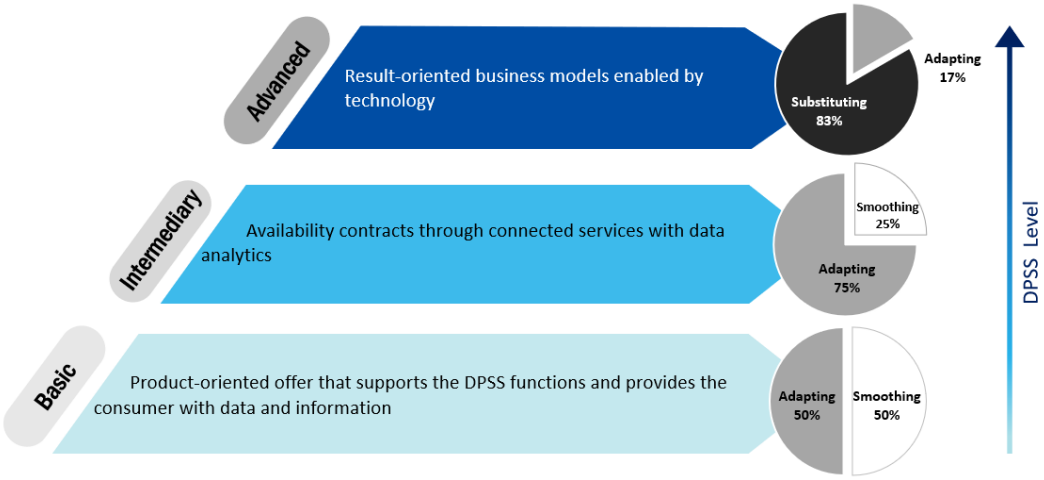


Figure 7 - Servitization pathways and DPSS relationship

As presented in **Figure 7**, in the Basic DPSS level, analyzing 28 cases in literature, it was possible to observe that providers that developed only Basic DPSS capabilities restrict its application to smoothing (50% cases) and adapting servitization strategies (50% cases), without cases reported as substituting. First, providers usually employ digital technologies to smooth the utilization of its products by the customer. This is the case, for example, of a Transportation company using remote monitoring technologies to smooth the product usage and maintenance by collecting data from trains to conduct maintenance activities in order to achieve greater availability (Grubic, 2018; Grubic & Jennions, 2017). Other example is a Heavy machinery company that relies on basic-level DPSS to provide services that use collected data to intelligently adapt the machine to the operations and conditions where the equipment is located (Lenka et al., 2017). While the basic digital capabilities served as enablers for the servitization of these companies (Grubic, 2018), the mostly reactive characteristic of these DPSS levels does not provide enough technology and capabilities to support a more complex substituting servitization strategy, since no case study was observed in literature. This analysis leads us to state our first proposition:

Proposition 1: Basic DPSS mostly supports Smoothing and Adapting servitization strategies.

On the other hand, when analyzing the 20 case studies in the Intermediary level of DPSS, it is possible to observe that most of them (75%) correspond to an Adapting servitization strategy. Ives and Rodriguez (2016) report the case of an agricultural analytics firm that expands the functionality of moisture sensors and topographic data by crossing information from both sources to ensure that water requirements are satisfied efficiently, reducing the amount of water necessary. Another example of an intermediary-level DPSS that addresses an adapting strategy is reported by Jurčević et al., (2008). The authors discuss the case of a service that automates and facilitates the remote execution of a calibration service, in addition to the real-time processing of the results without the need for extra hardware.

A few cases (25%) encompassed the Intermediary level in a Smoothing strategy, which differed from the majority of the Intermediary cases. One example of this combination is presented by Kowalkowski et al. (2013) with the Toyota case study. In this case, Toyota Material Handling, which is a leading supplier of trucks and services, has collected wireless data from the customers' trucks and analyzed it over a web interface. Based on the analysis of this data, the company provides a fleet management service which allows customers to monitor and manage their fleet, smoothing the utilization of trucks by reducing costs and increasing productivity. Although not as common as the Intermediary and Adapting combination, this is a rather interesting cross between strategies that provides insights into new business models. This analysis leads us to state our second proposition:

Proposition 2: Intermediary DPSS mostly supports an Adapting servitization strategy and rarely supports a Smoothing servitization strategy

Finally, when analyzing the 12 case studies in the Advanced DPSS level, almost all corresponded to a Substituting servitization strategy. For instance, Ardolino et al. (2017) reports the case of Canon, a company that provides a pay-per-page contract. This BM in which the customer pays for the printed pages, demands Canon to pursue a high level of availability, in order to allow customers to print as much copies as they want, relying on a real-time connectivity with Canon's systems, for contract information, data collection and accurate invoicing. This connectivity reduced doubts, complexity and costs due to hardware or software modifications.

Although Advanced and Substituting strategies are strongly linked, we found 2 cases that presented an Advanced DPSS but through an Adapting servitization strategy. One of them is the case reported by Lerch and Gotsch (2015) of a machine tool manufacturer who implemented an availability contract grounded on the data of availability and lifecycle costs of the various components of the machine. The company also used the data to provide customers with upgrades, making the DPSS more automated and independent, through software updates or more efficient and powerful, through new or extended physical or service modules. This was achieved by the company due to the data analysis of historical information, transparence and controllability enabled by the ubiquitous connectivity and data. Such configuration can be explained by a strategic choice of the DPSS provider, that chooses not to offer its DPSS as a service but still through a product-centric approach despite the increased predictability, reliability, data and control it now offers.

Despite some special cases, clearly, advanced digital capabilities developed by providers in this higher level of DPSS motivates and supports a servitization strategy of substituting product selling by a service offer in which data and connectivity are fundamental to the providers' operation, profitability and predictability. In this sense although exceptions are possible, they are rare. This analysis leads us to state our third proposition:

Proposition 3: Advanced DPSS mostly support a Substituting servitization strategy.

Thus, in summary, although we identified different levels of DPSS offer, their necessary capabilities and uses, our analysis identified that, generally, the services offered in the DPSS mostly consists of maintenance-related services, especially in the most basic levels. Such finding may be explained by the low maturity level still present in this offer which leads to companies offering simpler services. In this sense DPSS companies that aim to differ from such competition should provide new uses for the data collected, improving its offer through, for example, DPSS modularity, simulations, optimizations, consultancy and upgrades. Also, as proposed by Lerch and Gotsch (2015), companies leaning toward the servitization direction must identify customers' needs and what is the potential when moving into these new markets in order to better conduct this servitization path.

5 CONCLUSIONS

5.1 Theoretical contributions

Our research is valuable since it presents a whole new landscape for each level of a DPSS offer along with their capabilities. In this sense, our article provides a unique and

aggregative framework that addresses the factors that compose a DPSS classification, such as the business model, the risk management, type of service attached and data use. Therefore, our classification comprises a set of factors that aim to not only characterize the level of the service, but also provides a common language when addressing DPSS. In this sense our article contributes to literature since no other study has developed such a comprehensive study on the cases studied in DPSS research. Also, we provide an overview of the necessary capabilities demanded for the provision of each DPSS level, which provides 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.

This article also provides an overview of how DPSS levels relate to each servitization pathway. Our results show that, the more advanced the DPSS level, the more servitized its offer tend to become. This finding is important since authors generally assume such relationship, however it was not specifically addressed to date. In addition, this study provides insights on the extent of such relationship and how practitioners and researchers can leverage such information to improve their knowledge on the servitization field. In this sense, we demonstrate two entering ways that can be followed by product companies toward a DPSS offer. While some servitized companies can use digital technologies to support their existing PSS, it is clear that the most revolutionary impact of digitization is in the contrary path, i.e. product companies that see servitization opportunities because they are adding digital technologies to their products.

5.2 Managerial implications

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. Therefore, it prevents product companies to venture in servitization strategies without holding the necessary capabilities for the entire delivery of the DPSS package. For instance, companies that would like to offer a basic DPSS, should be aware of the necessity of offering remote access, data analysis and monitoring and control capabilities. Just developing one of these capabilities could lead to an incomplete solution that would limit the value added to the customer, or even deliver an offer in which the customer does not perceive any value. As for example, if remote access service is offered to the potential customers without data analysis capability, unless someone in customer's company is able to analyze this data, no value would be perceived in the DPSS offer.

Therefore, with the three levels proposed in this article, companies seeking to offer digitally-servitized offers through DPSS that decide which digital technologies to incorporate to its products based on the chosen servitization strategy are able to do smarter investments that will bring more value to its customers. In other words, instead of being reactive and implementing digital technologies first to only then analyze what services could be offered, product companies should consider which services they want to offer and then understand which digital technologies will be added to the product and which digital capabilities should be developed to reach this objective. Such analysis can be done considering the capabilities here presented and their use according to each DPSS. This study also adds substantial managerial contributions in the sense that we provide insights into the different factors that encompass each DPSS level, since earlier studies proposing classifications usually neglect important factors for its offering, addressing specific subjects, such as the use of data, or the business model, but

without providing a holistic view. In this sense we provide several contributions for the necessary capabilities of each DPSS level according to their expected contributions and business models. It is, however, important to highlight that the DPSS company must consider other context-specific factors, which can affect its DPSS offer.

5.3 Limitations and future research

Some important capabilities not associated with the digital ones were not analyzed in this study. For instance, the financial aspects and capabilities that support different BM configurations for companies to develop and implement a safe and sustainable digitally-servitized offer. Therefore, we understand this aspect should be addressed in future studies due to its importance for the offer.

Also, DPSS presents, along with several benefits, some consequences such as increased complexity, demand for resources and competencies and the necessity of a closer collaboration between manufacturing firms and electronic equipment providers. Therefore, future studies should address these and other barriers for the DPSS offer as well as the drivers that evolve a DPSS offer and adoption.

Other than the benefits already presented, DPSS can also improve cross-functional communication and better service delivery strategies and quality through the customization enabled by technology (Antioco, Moenaert, Lindgreen, & Wetzels, 2008). Nevertheless, ICT alone do not provide the necessary differentiation for DPSS (Kowalkowski et al., 2013), instead they enable new practices that are capable of providing the competitive advantages (Brown and Hagel, 2003). Therefore, by redesigning service processes, deepening customer relationships or launching new services (Kowalkowski and Brehmer, 2008; Normann, 2001), ICTs consequently harden competition (Miller and Friesen, 1984) with offers that are more difficult to imitate. Therefore, although such advantages are severely pursued by the companies, changes are necessary not only in internal aspects of the company, such as design, service, marketing, human resources and security, but also on external aspects, such as competition, cooperation and the development of new skills and capabilities (Ardolino et al., 2017; Porter & Heppelmann, 2014b, 2015). These aspects also call for future research interest as a means to provide further understanding on DPSS offer and digital servitization strategies.

Our study also presents a limitation in the sense that we only provide an industrial view of DPSS. However, research is also necessary on the end customer field, since few studies have addressed this scope. Also, we suggest researchers to develop quantitative studies on this field due to the massive qualitative focus adopted by researchers lately. Such approach is necessary to advance in the theory building process by providing more analytical investigations instead of the descriptive views mostly applied in DPSS studies to date.

REFERENCES

Abdelwahab, S., Hamdaoui, B., Guizani, M., & Rayes, A. (2014). Enabling Smart Cloud Services Through Remote Sensing: An Internet of Everything Enabler. *IEEE Internet of Things Journal*, *1*(3), 276–288. https://doi.org/10.1109/JIOT.2014.2325071

Allmendinger, G., & Lombreglia, R. (2005). Four strategies for the age of smart services. *Harvard Business Review*, *83*(10), 131–4, 136, 138 passim. https://doi.org/10.1225/R0510J

Antioco, M., Moenaert, R. K., Lindgreen, A., & Wetzels, M. G. M. (2008). Organizational antecedents to and consequences of service business orientations in manufacturing companies. *Journal of the Academy of Marketing Science*, *36*(3), 337–358. https://doi.org/10.1007/s11747-008-0085-1

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G., & Ruggeri, C. (2018). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *56*(6), 2116–2132. https://doi.org/10.1080/00207543.2017.1324224

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Ruggeri, C., Ardolino, M., … Gaiardelli, P. (2017). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *7543*(May), 0. https://doi.org/10.1080/00207543.2017.1324224

Ayala, N. F., Gerstlberger, W., & Frank, A. G. (2019). Managing servitization in product companies: the moderating role of service suppliers. *International Journal of Operations and Production Management*, *39*(1), 43–74. https://doi.org/10.1108/IJOPM-08-2017-0484

Ayala, N. F., Paslauski, C. A., Ghezzi, A., & Frank, A. G. (2017). Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *International Journal of Production Economics*, *193*(August 2016), 538–553. https://doi.org/10.1016/j.ijpe.2017.08.019

Baines, T. S. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., … Wilson, H. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. https://doi.org/10.1243/09544054JEM858

Belvedere, V., Grando, A., & Bielli, P. (2013). A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system. *International Journal of Production Research*, *51*(2), 410–426. https://doi.org/10.1080/00207543.2011.648278

Benssam, A., Berger, J., Boukhtouta, A., Debbabi, M., Ray, S., & Sahi, A. (2007). What middleware for network centric operations? *Knowledge-Based Systems*, *20*(3), 255–265. https://doi.org/10.1016/j.knosys.2006.05.020

Beuren, F. H., Gomes Ferreira, M. G., & Cauchick Miguel, P. A. (2013). Product-service systems: A literature review on integrated products and services. *Journal of Cleaner Production*, *47*, 222–231. https://doi.org/10.1016/j.jclepro.2012.12.028

Bisio, I., Garibotto, C., Grattarola, A., Lavagetto, F., & Sciarrone, A. (2018). Exploiting Context-Aware Capabilities over the Internet of Things for Industry 4.0 Applications. *IEEE Network*, *32*(3), 101–107. https://doi.org/10.1109/MNET.2018.1700355

Brad, S., Murar, M., & Brad, E. (2017). Design of smart connected manufacturing resources to enable changeability, reconfigurability and total-cost-of-ownership models in the factory-of-the-future. *International Journal of Production Research*, *7543*(November), 1–23. https://doi.org/10.1080/00207543.2017.1400705

Bustinza, O. F., Gomes, E., Vendrell-Herrero, F., & Tarba, S. Y. (2018). An organizational change framework for digital servitization: Evidence from the Veneto region. *Strategic Change*,

27(2), 111–119. https://doi.org/10.1002/jsc.2186

Caggiano, A. (2018). Cloud-based manufacturing process monitoring for smart diagnosis services. *International Journal of Computer Integrated Manufacturing*, *00*(00), 1–12. https://doi.org/10.1080/0951192X.2018.1425552

Candell, O., Karim, R., & Söderholm, P. (2009). eMaintenance-Information logistics for maintenance support. *Robotics and Computer-Integrated Manufacturing*, *25*(6), 937–944. https://doi.org/10.1016/j.rcim.2009.04.005

Cenamor, J., Rönnberg Sjödin, D., & Parida, V. (2017). Adopting a platform approach in servitization: Leveraging the value of digitization. *International Journal of Production Economics*, *192*(December 2016), 0–1. https://doi.org/10.1016/j.ijpe.2016.12.033

Chaâri, R., Ellouze, F., Koubâa, A., Qureshi, B., Pereira, N., Youssef, H., & Tovar, E. (2016). Cyber-physical systems clouds: A survey. *Computer Networks*, *108*, 260–278. https://doi.org/10.1016/j.comnet.2016.08.017

Chang, A. Y., Li, Y. Y., Hung, M. H., & Yen, T. F. (2013). Mobile monitoring and control framework with active-push and plug-and-play capabilities. *Assembly Automation*, *33*(4), 317–333. https://doi.org/10.1108/AA-10-2012-077

Chiou, R., Mookiah, P., & Kwon, Y. (2009). Manufacturing e-quality through integrated web-enabled computer vision and robotics. *International Journal of Advanced Manufacturing Technology*, *43*(7–8), 720–730. https://doi.org/10.1007/s00170-008-1747-3

Chowdhury, S., Haftor, D., & Pashkevich, N. (2018). Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review. *Procedia CIRP*, *73*, 26–31. https://doi.org/10.1016/j.procir.2018.03.333

Condry, M. W., & Nelson, C. B. (2016). Using Smart Edge IoT Devices for Safer, Rapid Response With Industry IoT Control Operations. *Proceedings of the IEEE*, *104*(5), 938–946. https://doi.org/10.1109/JPROC.2015.2513672

Coreynen, W., Matthyssens, P., & Van Bockhaven, W. (2015). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Industrial Marketing Management*, *60*, 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012

Cusumano, M. A., Kahl, S. j, & Suarez, F. F. (2015). Services, industry evolution, and the competitive strategies of product firms. *Strategic Management Journal*, *36*(4), 559–575. https://doi.org/10.1002/smj.2235

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*(December 2017), 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

Demirkan, H., & Delen, D. (2013). Leveraging the capabilities of service-oriented decision support systems: Putting analytics and big data in cloud. *Decision Support Systems*, *55*(1), 412–421. https://doi.org/10.1016/j.dss.2012.05.048

Diakostefanis, M., Nikolaidis, T., Sampath, S., & Triantafyllou, T. (2017). Remote operation and monitoring of a micro aero gas turbine. *Aeronautical Journal*, *121*(1242), 1051–1065. https://doi.org/10.1017/aer.2017.50

Du, S., Liu, B., Ma, H., Wu, G., & Wu, P. (2018). IIOT-Based Intelligent Control and Management System for Motorcycle Endurance Test. *IEEE Access*, *3536*(c). https://doi.org/8367739

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*(January), 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*(January), 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Gago, D., & Rubalcaba, L. (2007). Innovation and ICT in service firms: Towards a multidimensional approach for impact assessment. *Journal of Evolutionary Economics*, *17*(1), 25–44. https://doi.org/10.1007/s00191-006-0030-8

Grubic, T. (2014). Servitization and remote monitoring technology. *Journal of Manufacturing Technology Management*, *25*(1), 100–124. https://doi.org/10.1108/JMTM-05-2012-0056

Grubic, T. (2018). Remote monitoring technology and servitization: Exploring the relationship. *Computers in Industry*, *100*, 148–158. https://doi.org/10.1016/j.compind.2018.05.002

Grubic, T. (2018). Remote monitoring technology and servitization: Exploring the relationship. *Computers in Industry*, *100*(December 2017), 148–158. https://doi.org/10.1016/j.compind.2018.05.002

Grubic, T., & Jennions, I. (2017). Remote monitoring technology and servitised strategies – factors characterising the organisational application. *International Journal of Production Research*, *7543*(May), 1–17. https://doi.org/10.1080/00207543.2017.1332791

Grubic, T., & Peppard, J. (2016). Servitized manufacturing firms competing through remote monitoring technology An exploratory study. *Journal of Manufacturing Technology Management*, *27*(2), 154–184. https://doi.org/10.1108/JMTM-05-2014-0061

Helfat, C. E., Finkelstein, S., Mitchell, W., Peteraf, M., Singh, H., Teece, D., & Winter, S. G. (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 Quarterly Executive*, *15*(4), 297–318. Retrieved from http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=bth%7B&%7DAN=120565633%7B&%7Dsite=ehost-live

Holmström, J., Liotta, G., & Chaudhuri, A. (2018). Sustainability outcomes through direct digital manufacturing-based operational practices: A design theory approach. *Journal of Cleaner Production*, *167*, 951–961. https://doi.org/10.1016/j.jclepro.2017.03.092

Holmström, J., & Partanen, J. (2014). Digital manufacturing-driven transformations of service supply chains for complex products. *Supply Chain Management: An International Journal*, *19*(4), 5. https://doi.org/10.1108/SCM-10-2013-0387

Hung, M. H., Chen, K. Y., Ho, R. W., & Cheng, F. T. (2003). Development of an e-Diagnostics/Maintenance framework for semiconductor factories with security considerations. *Advanced Engineering Informatics*, *17*(3–4), 165–178. https://doi.org/10.1016/j.aei.2004.07.004

Ives, Joaquin A. Rodriguez, & Biagio Palese. (2016). Enhancing Customer Service through the Internet of Things and Digital Data Streams. *MIS Quarterly Executive*, *15*(4), 279–297. Retrieved from http://www.misqe.org/ojs2/index.php/misqe/article/viewFile/728/444

Jiang, P., & Chen, B. (2007). Some key issues on enabling e-manufacturing as a part of product-driven e-business process via e-service. *International Journal of Manufacturing Technology and Management*, *10*(4), 380–399. https://doi.org/10.1504/IJMTM.2007.012156

Jitpaiboon, T., Dobrzykowski, D. D., Ragu-Nathan, T. S., & Vonderembse, M. A. (2013). Unpacking IT use and integration for mass customisation: A service-dominant logic view. *International Journal of Production Research*, *51*(8), 2527–2547. https://doi.org/10.1080/00207543.2012.720727

Jonsson, K., Holmström, J., & Lyytinen, K. (2009). Turn to the material: Remote diagnostics

systems and new forms of boundary-spanning. *Information and Organization*, *19*(4), 233–252. https://doi.org/10.1016/j.infoandorg.2009.07.001

Jurčević, M., Boršić, M., Malarić, R., & Hegeduš, H. (2008). Internet-enabled calibration services: Design of a secure calibration system. *IEEE Transactions on Instrumentation and Measurement*, *57*(9), 2012–2018. https://doi.org/10.1109/TIM.2008.919019

Kim, K. J., & Shin, D.-H. (2015). An acceptance model for smart watches. *Internet Research*, *25*(4), 527–541. https://doi.org/10.1108/IntR-05-2014-0126

Kiritsis, D. (2011). Closed-loop PLM for intelligent products in the era of the Internet of things. *CAD Computer Aided Design*, *43*(5), 479–501. https://doi.org/10.1016/j.cad.2010.03.002

Kowalkowski, C., Gebauer, H., & Oliva, R. (2017). Service growth in product firms: Past, present, and future. *Industrial Marketing Management*, *60*, 82–88. https://doi.org/10.1016/j.indmarman.2016.10.015

Kowalkowski, C., Kindström, D., & Gebauer, H. (2013). ICT as a catalyst for service business orientation. *Journal of Business & Industrial Marketing*, *28*(6), 506–513. https://doi.org/10.1108/JBIM-04-2013-0096

Kowalkowski, C., Windahl, C., Kindström, D., & Gebauer, H. (2015). What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies. *Industrial Marketing Management*, *45*(1), 59–69. https://doi.org/10.1016/j.indmarman.2015.02.016

Lenka, S., Parida, V., & Wincent, J. (2017). Digitization Capabilities as Enablers of Value Co-Creation in Servitizing Firms. *Psychology & Marketing*, *34*(1), 92–100. https://doi.org/10.1002/mar.20975

Lerch, C., & Gotsch, M. (2015). Digitalized Product-Service Systems in Manufacturing Firms : A Case Study Analysis Digitalized Product-Service Systems in Manufacturing Firms, *6308*. https://doi.org/10.5437/08956308X5805357

Liu, C., Zha, X. F., Miao, Y., & Lee, J. (2005). Internet server controller based intelligent maintenance system for information appliance products. *International Journal of Knowledge-Based and Intelligent Engineering Systems*, *9*(2), 137–148. https://doi.org/10.3233/KES-2005-9208

Mani, Z., & Chouk, I. (2017). Drivers of consumers' resistance to smart products. *Journal of Marketing Management*, *00*(00), 1–22. https://doi.org/10.1080/0267257X.2016.1245212

Marinova, D., de Ruyter, K., Huang, M. H., Meuter, M. L., & Challagalla, G. (2017). Getting Smart: Learning From Technology-Empowered Frontline Interactions. *Journal of Service Research*, *20*(1), 29–42. https://doi.org/10.1177/1094670516679273

Megliola, M., Sanguini, R., & Sesana, M. (2015). Adaptive Video Streaming for Technology-Enhanced Learning in Workplaces. *Journal of E-Learning and Knowledge Society*, *11*(2), 129–142. https://doi.org/10.20368/1971-8829/1009

Nambisan, S. (2013). Journal of the Association for Information Information Technology and Product / Service Innovation : A Brief Assessment and Some Suggestions for Future Research Information Technology and Product / Service Suggestions for Future Research. *Journal of the Association for Information Systems*, *14*(SI), 215–226.

Ness, D., Swift, J., Ranasinghe, D. C., Xing, K., & Soebarto, V. (2015). Smart steel: New paradigms for the reuse of steel enabled by digital tracking and modelling. *Journal of Cleaner Production*, *98*, 292–303. https://doi.org/10.1016/j.jclepro.2014.08.055

Nylén, D., & Holmstrom, J. (2015). Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Business Horizons*, *58*(1), 57–67. https://doi.org/10.1016/j.bushor.2014.09.001

Okathe, T., Heydari, S. S., Sood, V., Cole, O., & El-Khatib, K. (2016). Middleware for smart heterogeneous critical infrastructure networks intercommunication. *International Journal on Smart Sensing and Intelligent Systems*, *9*(3), 1261–1286.

Ong, M. H., West, A. A., Lee, S. M., & Harrison, R. (2007). The opportunities for multimedia supported remote maintenance provided by an implementation of a component-based system in the automotive domain. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(5), 787–798. https://doi.org/10.1243/09544054JEM620

Opazo-Basáez, M., Vendrell-Herrero, F., & Bustinza, O. (2018). Uncovering Productivity Gains of Digital and Green Servitization: Implications from the Automotive Industry. *Sustainability*, *10*(5), 1524. https://doi.org/10.3390/su10051524

Ostrom, A. L., Parasuraman, A., Bowen, D. E., Patrício, L., & Voss, C. A. (2015). Service Research Priorities in a Rapidly Changing Context. *Journal of Service Research*, *18*(2), 127–159. https://doi.org/10.1177/1094670515576315

Pagoropoulos, A., Maier, A., & McAloone, T. C. (2017). Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry. *Journal of Cleaner Production*, *166*, 369–380. https://doi.org/10.1016/j.jclepro.2017.08.019

Paluch, S. (2014). Customer expectations of remote maintenance services in the medical equipment industry. *Journal of Service Management*, *25*(5), 639–653. https://doi.org/10.1108/JOSM-07-2013-0195

Parida, V., Sjödin, D. R., Lenka, S., & Wincent, J. (2015). Developing Global Service Innovation Capabilities: How Global Manufacturers Address the Challenges of Market Heterogeneity. *Research-Technology Management*, *58*(5), 35–44. https://doi.org/10.5437/08956308X5805360

Porter, M. E., & Heppelmann, J. E. (2014). How Smart, Connected Product Are Transforming Competition. *Harvard Business Review*, 64–89. https://doi.org/10.1017/CBO9781107415324.004

Porter, M., & Heppelmann, J. (2015). How smart, conected products are transforming companies. *Harvard Business Review*, (October). https://doi.org/10.1017/CBO9781107415324.004

Reim, W., Parida, V., & Örtqvist, D. (2015). Product-Service Systems (PSS) business models and tactics - A systematic literature review. *Journal of Cleaner Production*, *97*, 61–75. https://doi.org/10.1016/j.jclepro.2014.07.003

Rönnberg Sjödin, D., Parida, V., & Kohtamäki, M. (2016). Capability configurations for advanced service offerings in manufacturing firms: Using fuzzy set qualitative comparative analysis. *Journal of Business Research*, *69*(11), 5330–5335. https://doi.org/10.1016/j.jbusres.2016.04.133

Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics*, *192*, 92–105. https://doi.org/https://doi.org/10.1016/j.ijpe.2017.02.016

Smith, D. J. (2013). Power-by-the-hour: The role of technology in reshaping business strategy at Rolls-Royce. *Technology Analysis and Strategic Management*, *25*(8), 987–1007. https://doi.org/10.1080/09537325.2013.823147

Song, Z., & Moon, Y. (2017). Assessing sustainability benefits of cybermanufacturing systems. *International Journal of Advanced Manufacturing Technology*, *90*(5–8), 1365–1382. https://doi.org/10.1007/s00170-016-9428-0

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing

Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Troilo, G., De Luca, L. M., & Guenzi, P. (2017). Linking Data-Rich Environments with Service Innovation in Incumbent Firms: A Conceptual Framework and Research Propositions. *Journal of Product Innovation Management*, *34*(5), 617–639. https://doi.org/10.1111/jpim.12395

Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment*, *13*(4), 246–260. https://doi.org/10.1002/bse.414

Valencia, A., Mugge, R., Schoormans, J. P. L., & Schifferstein, H. N. J. (2015). The design of smart product-service systems (PSSs): An exploration of design characteristics. *International Journal of Design*, *9*(1), 13–28. https://doi.org/10.1016/j.procir.2016.04.078

Vandermerwe, S., & Rada, J. (1988). Servitization of business: Adding value by adding services. *European Management Journal*, 314–324. https://doi.org/10.1016/0263-2373(88)90033-3

Vardar, C., Gel, E. S., & Fowler, J. W. (2007). A framework for evaluating remote diagnostics investment decisions for semiconductor equipment suppliers. *European Journal of Operational Research*, *180*(3), 1411–1426. https://doi.org/10.1016/j.ejor.2006.05.020

Vendrell-Herrero, F., Wilson, J. R., & Wilson, F. V. J. R. (2017). Servitization for territorial competitiveness: taxonomy and research agenda. *Competitiveness Review*, *27*(1), 2–11. https://doi.org/10.1108/CR-02-2016-0005

Vinet, L., & Zhedanov, A. (2011). A 'missing' family of classical orthogonal polynomials. *Journal of Physics A: Mathematical and Theoretical*, *44*(8), 085201. https://doi.org/10.1088/1751-8113/44/8/085201

Visnjic, I., Ringov, D., & Arts, S. (n.d.). Which Service? How Industry Conditions Shape Firms' Service-Type Choices. *Journal of Product Innovation Management*, *0*(0). https://doi.org/10.1111/jpim.12483

Wu, B., Zhou, B., & Xi, L. (2007). Remote multi-robot monitoring and control system based on MMS and web services. *Industrial Robot: An International Journal*, *34*(3), 225–239. https://doi.org/10.1108/01439910710738863

Wu, D., Terpenny, J., & Schaefer, D. (2017). Digital design and manufacturing on the cloud: A review of software and services. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *31*(01), 104–118. https://doi.org/10.1017/S0890060416000305

Wuenderlich, N. V., Heinonen, K., Ostrom, A. L., Patricio, L., Sousa, R., Voss, C., & Lemmink, J. G. A. M. (2015). "Futurizing" smart service: implications for service researchers and managers. *Journal of Services Marketing*, *29*(6/7), 442–447. https://doi.org/10.1108/JSM-01-2015-0040

Zaeh, M. F., Reinhart, G., Ostgathe, M., Geiger, F., & Lau, C. (2010). A holistic approach for the cognitive control of production systems. *Advanced Engineering Informatics*, *24*(3), 300–307. https://doi.org/10.1016/j.aei.2010.05.014

Zhu, Z., Zhao, J., Tang, X., & Zhang, Y. (2015). Leveraging e-business process for business value: A layered structure perspective. *Information and Management*, *52*(6), 679–691. https://doi.org/10.1016/j.im.2015.05.004

ANNEX A

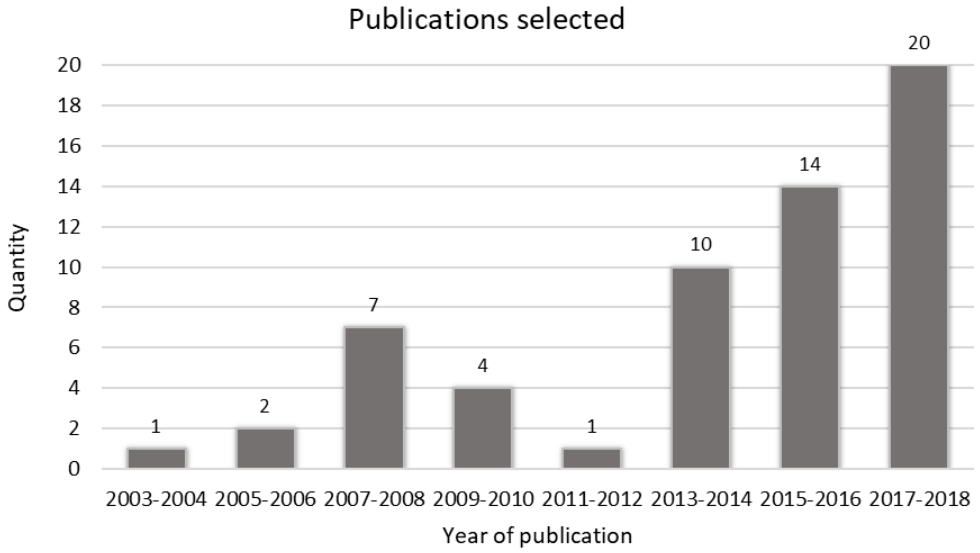
Journals and publications

n	Journal	Publications

5	International Journal of Production Research	Brad et al., (2017); Jitpaiboon et al., (2013); Grubic and Jennions (2017); Ardolino et al., (2017); Belvedere et al., (2013)
3	Journal of Cleaner Production	Pagoropoulos et al., (2015); Holmström et al., (2018); Ness et al., (2015)
2	Advanced Engineering Informatics	Hung et al., (2003); Zaeh et al., (2010)
2	Harvard Business Review	Allmendinger and Lombreglia (2005); Porter and Heppelmann (2014)
2	International Journal of Advanced Manufacturing Technology	Chiou et al., (2009); Song and Moon (2017)
2	Journal of Manufacturing Technology Management	Gubric (2014); Grubic and Peppard (2016)
2	Journal of Service Research	Ostrom et al., (2015); Marinova et al., (2017)
2	Mis Quarterly Executive	Herterich et al., (2016); Ives and Rodriguez (2016)
2	Research Technology Management	Parida et al., (2015); Lenka et al., (2017)
2	International Journal of Production Economics	Cenamor et al., (2017); Rymaszewska et al., (2017)
35	Other Journals (with 1 publication each)	Diakostefanis et al., (2017); Wu et al., (2017); Chang et al. (2013); Chaâri et al., (2016); Demirkan and Delen (2013); Vardar et al., (2007); Du et al., (2018); Abdelwahab et al., (2014); Bisio et al., (2018); Jurčević et al., (2008); Coreynen et al., (2016); Wu et al., (2007); Zhu et al., (2015); Jonsson et al., (2009); Caggiano (2018); Liu et al., (2005); Jiang and Chen (2007); Okathe et al., (2016); Megliola et al., (2015); Troilo et al., (2017); Benssam et al., (2007); Condry and Nelson (2016); Ong et al., (2007); Lenka et al., (2017); Candell et al., (2009); Bustinza et al., (2018); Opazo-Basáez et al., (2018); Smith (2013); Kiritsis (2011); Kowalkowski et al., (2013); Paluch (2014); Wuenderlich et al., (2015); Chowdhury et al., (2018); Gago and Rubalcaba (2007); Gubric (2018)
59		

ANNEX B

Quantity of publications selected (organized in 2-year periods)



4 ARTICLE 3 - DRIVERS AND BARRIERS TO THE OFFER AND THE ADOPTION OF DIGITAL PRODUCT-SERVICE SYSTEMS

Abstract
Digital Product-Service Systems have been considered as the new generation of solutions of servitization, considering instead of manual services being offered, digital solutions and platforms such as sensors, software and algorithms that can allow to offer a more valuable service to the customer. However, despite of the increasing attention given by the academia and practitioners to this new trend, there is a lack of understanding on the factors that allows or not their offering by product firms. Therefore, we aim to identify the barriers and drivers for DPSS through both the organizational and operational perspectives and the dimensions that compose both perspectives. Specifically, this research aims to understand these aspects and the differences with the theoretical state-of-the-art. Therefore, based on a framework of analysis developed through a literature review on the theme we identify the barriers and drivers for a DPSS offer and adoption according to the analysis of 6 case studies conducted in Brazilian companies. Our results show that the DPSS context is composed of seven dimensions: risk management, value proposition, relationship-based business model, DPSS offer, DPSS adoption, remote access and data, and customer-oriented R&D. Also, the findings on each DPSS level show DPSS providers identify more barriers and drivers in the operational perspective. However, in advanced levels, providers perceive more drivers in the organizational aspects of the offer, since the business model and the value offer rely on more complex activities, that increase the value delivery.

Keywords: PSS; Developing Countries; Information and Communication Technologies; Digitization; Digital Technologies

1 INTRODUCTION

Nowadays customers continuously seek more customized and sustainable offers, which leads to the search for product-service systems (PSS) (Baines *et al.*, 2007). PSS are a special case of a servitization process that extends the traditional functionality of a product through the incorporation of services (Baines et al., 2007; Kowalkowski, Gebauer, & Oliva, 2017) changing the business model of companies (Ayala, Paslauski, Ghezzi, & Frank, 2017). This addition of services enables companies to obtain financial gains, due to the higher profit margins of services (Lightfoot, Baines, & Smart, 2013) and relationship benefits, derived from the personal nature of the services (Baines et al., 2007).

In this context, digital technologies can improve existing products and enable new services, with new ways to customize and segment consumers (Porter & Heppelmann, 2015; Rymaszewska, Helo, & Gunasekaran, 2017). The fundamental role

of digital technologies to leverage PSS delivery is currently unquestionable (Coreynen, Matthyssens, & Van Bockhaven, 2015; Kowalkowski, Kindström, & Gebauer, 2013), given that digital technologies are increasingly embedded in the core of products, services, and firm's operations (Yoo, Boland, Lyytinen, & Majchrzak, 2012). This addition of digital technologies to the PSS is named Digital Product-Service Systems (DPSS), which is a variation of the PSS offer. The DPSS is characterized by the combination of a product with digitally enabled services (Ardolino et al., 2017; Lerch & Gotsch, 2015b; S. A. Rijsdijk & Hultink, 2009) that can deliver value through monitoring, remote access, data, optimization services, etc. (Grubic, 2018; Rymaszewska et al., 2017a).

Given the technology utilized, DPSS can change the way users relate to products, allowing them to perform tasks that were previously only possible manually (Yin, 2011) such as training, maintenance, prevention of failures (Lerch & Gotsch, 2015), better understanding of the products' functioning and use (Coreynen et al., 2015), along with several other benefits. Despite the benefits mentioned, the implementation of DPSS within industries can encounter barriers (Bouwman, Carlsson, Molina-Castillo, & Walden, 2007; Mani & Chouk, 2017). Implementing DPSS requires knowledge related to technologies, such as cloud computing, predictive analytics, internet of things, etc. (Ardolino et al., 2017) and even new business models, based on results, data, or equipment use (Lerch & Gotsch, 2015; Opresnik & Taisch, 2015; Porter & Heppelmann, 2014a). Literature, however, does not present a systematization of the barriers and drivers faced by companies that offer or adopt a DPSS, which could provide companies with guidelines in this process. Thus, aiming to address a DPSS research gap this article seeks to answer the following research questions: *what are the barriers and drivers for the offer and the adoption of DPSS and how are they structured?* Also, our study aims to answer the following question: *what are the barriers and drivers for a DPSS that arise in a developing country?* Given that the majority of studies only addresses developed countries - i.e.:(Ardolino et al., 2017; Grubic, 2018; Lerch & Gotsch, 2015; Rymaszewska et al., 2017a).

Therefore, this article conducts a literature review and empirical case studies, to identify the relations between provider, customer and DPSS and what types of barriers and drivers companies should expect to face when offering or adopting a DPSS. Our analysis shows that in the organizational perspective the most important barrier faced by companies is the lack of value perception by customers who adopt DPSS, whereas the

most important driver is the increased relationship enabled by DPSS business model. In the operational perspective, however, the most important barrier is composed of contextual problems of the Brazilian infrastructure, such as importation bureaucracy and poor internet access. Whereas the increased search for such offer and the use of remote access and data to provide innovative services are the most important drivers in the operational perspective.

2 THEORETICAL BACKGROUND

2.1 DIGITAL PRODUCT-SERVICE SYSTEM

DPSS is an emergent field within the servitization literature (Ardolino, Saccani, Gaiardelli, & Rapaccini, 2016). This offer can be divided into three different levels, being: (i) basic, (ii) intermediary and (iii) advanced (Marcon et al., 2019). In the (i) basic level companies offer services that support the operation of the company in a reactive way, that are human-dependent. The basic level demands more basic technologies since it is focused in the supply of information through monitoring, remote diagnosis, sensing and control. It is therefore centered on monitoring and control, triggering and demanding human actions. In the (ii) intermediary level the focus of the DPSS is in providing complementary services to the original function of the product. Such type of services is enabled by analytical technologies, that not only collect data, such as the basic level, but also analyze this information to anticipate breakdowns, increase performance and optimize process or the machine's operation. With such amount of data companies can provide more advanced services focused on the customization, consulting and personalized trainings. In this level, using the data collected companies can feedback their R&D to develop products that better address customers' needs based on real data of the product's operation. The intermediary level differs from the basic level since it enables autonomous decisions, due to the great amount of data available and its analysis. In the (iii) advanced level more advanced technologies are employed, such as predictive analytics, constant connectivity and simulations so that companies can offer services based on the actual productivity, availability or the use of a given machine. This type of innovation is enabled by the greater level of reliability, control and prediction of an equipment's behavior and operation. In this sense, the different levels of DPSS deliver value in different ways to customers in each level, in this sense, offering different DPSS levels can lead to different drivers and barriers given its complexity. In this sense, basic DPSS are

expected to present less complex barriers and drivers due to its incipient value offer, such as the necessary digital capabilities, whereas, more innovative DPSS, such as in the advanced level, the barriers and drivers are expected to be more difficult to be overcome, since the technologies involved and the business model attached to it are necessarily more complex and innovative, such as the increased dependence by the customer, or the financial risks associated to such investment. Therefore, given that several differences on a DPSS occur due to the DPSS level, as seen on the previous chapter of this dissertation, we segment our analysis on the study of the drivers and barriers according to the DPSS levels. By analyzing the drivers and the barriers that compose the DPSS through levels we can provide more accurate implications toward each offer.

2.2 DPSS DRIVERS AND BARRIERS

DPSS are boosted by emerging aspects in companies that seek increasing amounts of data to support decision making (Grubic, 2014). In this sense, literature presents several drivers for DPSS offer. Drivers are here understood as the motivations underlying the decision of developing or adopting a DPSS, as it is proposed in the study of Annarelli, Battistella and Nonino (2016) in the field of PSS. Some of the DPSS drivers are closer contact with suppliers which results in better relationships (Coreynen et al., 2015), developing customer loyalty (Herterich, Uebernickel, & Brenner, 2016). Besides the benefits for customers, the DPSS supplier also has benefits enabled by contracts based on availability, use (Grubic, 2018) and performance (Coreynen et al., 2015) or by enabling more precise contractual guarantees based on the data from user history (Grubic, 2018). However, no article has provided a systematization of the drivers for DPSS in literature, which is also true to the DPSS barriers, despite the constant search of industry for smarter offers and a more automated production. One of the main barriers found both for suppliers and for customers (other industries) is related to the product-centric view of companies that leads to a lack of a mature service culture (Coreynen et al., 2015) hindering the offer and adoption of DPSS (Grubic, 2014). Also, companies, usually find barriers in effectively communicating the value proposition to the customer (Grubic, 2014), since some of them cannot properly convince the customer with the improvements delivered by the offer. On the other side, customers do not fully comprehend the benefits of a DPSS (Grubic & Jennions, 2017a) and are not completely

convicted of the potentials generated by this type of offer given the intangibility of the services delivered (Paluch, 2014).

2.3 DPSS DIMENSIONS

The dimensions here encompass the aspects related to the DPSS, from both the customer's and, also, the provider's viewpoint. The dimensions here presented will guide the analysis of the results from both the literature review and the case studies. In this sense, based on a literature analysis on the DPSS concept one of the most relevant dimensions for a DPSS offer and adoption is the **risk management** (Grubic, 2018). This dimension is important to customers since they understand the risk reduction as a greater benefit than cost savings (Grubic, 2018) in DPSS offers. To the DPSS provider, the risk assumed, especially in more complex business models, can be diminished through the use of data or the knowledge on the production operation (Grubic, 2018; Lerch & Gotsch, 2015). Risk management is understood as uncertainties, complexities, or even investments with unsure returns, that must be managed by the provider or the customer, depending on the agreements made, that derive from the DPSS, customer-provider relationship, equipment operation outsourcing, etc.

The **business model** is another dimension that changes in the DPSS context. This dimension refers to the business transactions, which in the DPSS are focused in building relationships between the provider and the customer, collaborations and loyalty-increasing offers. Because DPSS enables the provision of more advanced operations through the technologies inserted in it, providers can sell, for example, more precise availability and lifecycle guarantees contracts (Lerch & Gotsch, 2015). In this sense, there is an improvement in the relationship between parties, as they become more connected and dependent (Herterich et al., 2016).

In addition to the business model, according to Grubic (2018) DPSS can benefit the dimensions of **offer** and **adoption**. In this sense, the DPSS adoption is comprehended by benefits such as the minimization of downtimes, proactively stopping or preventing breakdown, increased advantages to customers and functionalities (Rijsdijk, Hultink, & Diamantopoulos, 2007) . Whereas the DPSS offer is composed of benefits such as the reduction of costs, that enable increased profit margins, the reduction of costs and more accurate and proactive maintenance plans. The use of data to feedback R&D activities (Grubic, 2018) is mentioned as another benefit for the DPSS offer, however in our study this dimension will be analyzed separately, given its

increased relevance in the DPSS context, due to the possibilities of delivering differentiation and competitive advantages (Lerch & Gotsch, 2015).

The **Value proposition** is a subject widely treated in literature (Alejandro G Frank, Mendes, Ayala, & Ghezzi, 2019). This dimension treats the aspects that concern the value perception, given that DPSS is a rather new concept, the value it proposes and delivers are of increasing interest since this is an important aspect of the DPSS development, offer, and success (Porter & Heppelmann, 2015). Also, due to services' intangibility (Lerch & Gotsch, 2015), digital resistance (Mani & Chouk, 2016) or the difficulty faced by companies to clearly communicate the value proposal (Grubic, 2014), the value proposition is an topic that calls for further understanding especially in the analysis for DPSS drivers and barriers.

Remote access and data is also a fundamental characteristic for DPSS since it enables innovative value delivery forms such as data for diagnosis and monitoring (Coreynen et al., 2015; Herterich et al., 2016). It is also the main difference between regular PSS, which demands a detailed and separate dimension covering the services enabled by the connectivity, since the degree of digitization of the core products directly affect the degree of digitization of the accompanying services (Lerch & Gotsch, 2015). Therefore, this dimension also enables the delivery of innovative services, but also unexpected barriers.

Finally, another data-related dimension is the use of **data to feedback R&D activities.** Such dimension is proposed given its importance as one of the main benefits identified in the use of DPSS (Grubic, 2018). Although the data collected is highly subjective to interpretation, it can be translated into valuable information (Grubic, 2018; Lerch & Gotsch, 2015). In addition, such information can also foster business feedback to internal improvements (Frank et al., 2019).

Therefore, the barriers and drivers identified in the studies analyzed are structured in **Table 12** grounded on the dimensions proposed by literature. Currently, due to the recent emerging research in digital servitization and consequently, DPSS, research do not properly approach the barriers and drivers faced by the companies in general, and to our knowledge, no other study has approached DPSS in developing countries. In this sense, through a multiple case study, this study seeks to approach such problem in order to fulfill the gap in literature for DPSS research in developing countries, such as the focus of this study, namely the Brazilian setting, as will be introduced in the next section.

Table 12 - DPSS drivers and barriers dimensions and authors

	Dimensions / Authors	(Coreynen et al., 2015)	(Grubic, 2014)	(Grubic, 2018)	(Grubic & Jennions, 2017)	(Herterich et al., 2016)	(Kowalkowski et al., 2013)	(Lenka, Parida, & Wincent, 2017)	(Lerch & Gotsch, 2015)	(Pagoropoulos, Maier, & McAloone, 2017)	(Paluch, 2014)	(Porter & Heppelmann, 2014)	(Rymaszewska et al., 2017)
	Relationship-based Business Model												
Drivers	Improved customer relationships and support	X				X			X			X	
	Performance and availability-based business models	X		X					X				X
	Flexible and customized segmented offer					X	X	X				X	
	Support for new business models					X						X	X
	Deeper insights for business and partners that generates competitive advantages											X	X
	Stronger customer loyalty					X							
	Enables the offer of lifecycle cost guarantees and precise availability data.								X				
	More effective support of customer processes												X
Barriers	Need to develop new skills and internal capabilities inside the firm	X				X							
	Need to develop capabilities and skills through partners in value chain					X						X	
	Difficult adoption of a service perspective from senior management	X	X										
	Tight integration and engage is required with customers in the process	X						X					
	Remote access and data												
Drivers	Constant monitoring (KPI monitoring, quality management and results report)	X				X		X				X	X
	Preventive, proactive and reactive maintenance based on errors and repair needs								X			X	X
	Remote control and monitoring of machines reducing the time for repair		X						X			X	
	Data for diagnosis and prognostic information				X			X					
	Direct access to operational data with minimized chances of error		X										
	Improved knowledge about equipment's performance			X									
	Geolocation history											X	
	Companies could access data from the end user and provide insights on usage												X
Barriers	Data privacy and hacking possibilities demanding more secure networks										X	X	X
	Real-time data acquisition and transmission necessary for value creation			X				X	X				
	Customers' fear of change	X											
	Business and monitoring ethics may result in serious problems		X										
	Customers' willingness to share information of a problem or a failure				X								
	Necessary skills and knowledge of analysts to 'decipher' data collected				X								

	Dimensions / Authors	(Coreynen et al., 2015)	(Grubic, 2014)	(Grubic, 2018)	(Grubic & Jennions, 2017)	(Herterich et al., 2016)	(Kowalkowski et al., 2013)	(Lenka, Parida, & Wincent, 2017)	(Lerch & Gotsch, 2015)	(Pagoropoulos, Maier, & McAloone, 2017)	(Paluch, 2014)	(Porter & Heppelmann, 2014)	(Rymaszewska et al., 2017)
	Diagnostic and prognostic functionalities are still limited				X								
	Data can be unreliable, complex, overrated subject of errors		X									X	
	Customers strongly insist on regular information exchanges										X		
	Customer-oriented R&D												
Drivers	Insight into customers' needs and demands	X	X									X	X
	Information feedback for R&D of new product/services		X			X			X				
	Quicker product introductions												X
	Data used to predict customer's needs							X					
Barriers	Highly qualified personnel to take advantage of the data collected					X		X					
	Need to include customers' needs to avoid wrong requirement perception		X										
	Lack of focus on service aspects and too much focus on technical aspects		X										
	Risk Management												
Drivers	Mitigations of risks			X	X								
	Risk outsourcing		X		X								
	Reduced complexity within the firm	X											
Barriers	Investment uncertainty, not yielding the expected revenues	X	X										
	Necessary investments	X											
	Customers associate the technology with a high level of risk										X		
	Value Proposition												
Drivers	Remote support and advisory value propositions					X							X
	Remotely diagnosing a failure on a specific product.								X				
	Possibility of delivering value increasing revenues from exports sales								X				
	Value can be created by offering process analysis and consulting services.						X						
Barriers	Difficulty in defining benefits			X	X						X		
	Limited understanding about the true capabilities of by the customer				X						X		
	Difficulty in clearly communicating the value proposal to the customer.		X										
	Customers' lack of perception of value cocreation		X										
	DPSS Adoption												
Drivers	Reducing preventive and scheduled maintenance thus increasing uptime and availability			X					X				

	Dimensions / Authors	(Coreynen et al., 2015)	(Grubic, 2014)	(Grubic, 2018)	(Grubic & Jennions, 2017)	(Herterich et al., 2016)	(Kowalkowski et al., 2013)	(Lenka, Parida, & Wincent, 2017)	(Lerch & Gotsch, 2015)	(Pagoropoulos, Maier, & McAloone, 2017)	(Paluch, 2014)	(Porter & Heppelmann, 2014)	(Rymaszewska et al., 2017)
	Improved and optimized efficiency and effectiveness			X		X	X	X					
	Decrease in operating costs			X		X				X			
	Customized offer			X					X				
	Equipment increased life cycle			X									X
	Enhanced functionalities and intelligence through algorithms and autonomy							X				X	
	Reduced lead-time	X											
	Health safety improvement			X									
	Failure and breakdown anticipation					X							
	Continuous upgrade via software											X	
	System interoperability											X	
	Improved reliability												X
Barriers	Customers are reluctant to outsource a service	X											
	Unforeseen technical issues for customers	X											
	Senior management should overcome the product-centric mindset.		X										
	DPSS Offer												
Drivers	Maintenance optimization	X					X		X			X	X
	Accurate response to customers' demands			X				X	X				
	Improved customers' satisfaction due to better service capability						X				X		X
	Employee empowerment and increased satisfaction			X		X							
	Possibility of using the DPSS as a way to educate or market new products	X											
	Customer lock-in					X							
	Increased profitability												X
	Better control of the physical product, increasing asset life cycle												X
Barriers	Development of totally new competencies, resources, and collaborations.					X			X			X	
	Staff integration and, management of a diverse set of work styles and backgrounds					X			X			X	
	Customers still seek a personal interaction rather than a digital										X		
	Gap between potential and realized benefits.		X										
	Misalignment of strategies between the service design and product				X								

3 METHOD

This study was conducted through a qualitative approach with empirical case studies that focus on investigating a contemporary phenomenon within its actual context (Yin, 2003) and it is a useful tool to explore and develop theories, along with providing great practical usefulness (Voss, Tsikriktsis, & Frohlich, 2002) and enabling the comprehension of complex social problems (Eisenhardt & Graebner, 2007).

3.1 CASES SELECTION

A total of six cases were studied in this article. The choice for multiple cases is due to the better generalization, validity and the reduction of the possibility of researcher's bias affecting the results (Voss et al., 2002). Therefore, an important part of the study is the selection of the cases. In this sense, this study sought to study cases of companies located in Brazil, in different industrial sectors, as **Table 13** presents. Thus, we contacted companies that offered some type of DPSS, according to the second chapter of this dissertation (basic, intermediary and advanced). In addition, we selected companies of different sizes (small, medium and large enterprises) to better understand the behavior of a DPSS offer in different contexts. **Table 13** presents a brief summarization of the companies studied.

Table 13 – Cases' description

Company	Type of DPSS	Field	Size (Employees)	Interviewees
A	Basic	OEM for paving machines	300	Product engineer; Purchasing sector; Commercial sector;
B	Basic	Steel processing machines	45	Production manager; Automation engineer; Purchasing sector;
C	Basic	Industrial Automation	15	External sales sector; Application Engineer; Commercial director;
D	Intermediary	Industrial Automation	600	Application Engineers; Projects; Commercial;
E1	Intermediary	Additive manufacturing startup	6	Operations department; Strategic department;
E2	Advanced	Additive manufacturing startup	6	Operations department; Strategy director;

Initially we made contact through phone or e-mail, in order to the asses the companies' interest in participating in the research and were adequate to the requirements proposed and only then the next steps were conducted.

3.2 RESEARCH INSTRUMENT

The data from the cases studied were collected using a semi structured questionnaire with six open-ended questions of which three addressed the barriers and the three remaining questions addressed the drivers for a DPSS offer in Brazilian industries. The questionnaire was developed according to the literature on DPSS and the framework developed. A preliminary version of the instrument was tested with the researchers in a meeting, and changes were made to improve the questionnaire (Yin, 2003). We opted to send interviewees a brief explanation on the subject in advance, as a means to ease the comprehension on the subject, such as proposed by Voss, Tsikriktsis and Frohlich (2002).

The questionnaire used has the following questions:

1. What are the barriers in the DPSS offer? (Annarelli, Battistella, & Nonino, 2016)
2. What are the causes of these barriers? And what solutions would be possible to overcome these barriers?
3. What are the reasons that led the company to offer the DPSS?
4. What are the expected benefits? (Belvedere, Grando, & Bielli, 2013)
5. What is the use of the DPSS ?
6. What technologies are required for the development of DPSS for manufacturing?

3.3 DATA COLLECTION

Data collection followed the procedures suggested by Voss, Tsikriktsis, and Frohlich (2002), Yin (2003) and Eisenhardt and Graebner (2007) and were conducted through personal interviews or videoconference. We interviewed two to three employees of each company studied during thirty to ninety minutes from January to December, 2018. Each interview was conducted by at least two interviewers, who besides conducting the interview, recorded them and took notes (Eisenhardt & Graebner, 2007; Yin, 2003). Thus, we could transcript exactly the answers later and discuss any inconsistencies. If a subject was not approached or the answer was not complete, we contacted the interviewees later by e-mail in order to complement the data collected.

3.4 DATA ANALYSIS

Initially, after conducting the interviews, the recordings were transcript in their literacy. Later, each researcher individually analyzed each interview and the notes taken as a means to reduce any possible researcher bias (Voss et al., 2002). After individual analysis, a crossed analysis was conduct with the objective of identifying differences and convergences among companies, DPSS levels, sectors or other relevant characteristics (Ayala et al., 2017; Voss et al., 2002). Then we codified the results, extracted the data from the interviews and analyzed according to the constructs of the framework developed (Corbin & Strauss, 1990; Voss et al., 2002). These tasks were conducted in four meeting after the interviews with the article's authors, which enabled the result analysis.

4 RESULTS

The analysis of the results was conducted through two different perspectives. Initially we analyzed the types of the barriers and drivers experienced by companies, that is, if they are related to the dimensions of value proposition, remote access and data, adoption and offer, risk management, relationship-based business model and value proposition. The individual analysis was conducted based on the DPSS level provided by each company, as follows:

4.1 BASIC DPSS

4.1.1. Company A: The company offers a DPSS focused on monitoring and analysis of the data of paving equipment. The service offered is data analysis by the DPSS provider and through this service the company provides maintenance services. However, due to the incipient maturity of the company in the DPSS field, the service of data analysis is still manual.

According to the interviewees, the main barriers found by the company in this Basic-level DPSS were those related to the offer of a service-oriented offer, since according to the Product engineer: *"this subject is not part of our daily activities nowadays"*. Also, the interviewees mentioned a persistent use of manual work for data analysis, which might lead to misinterpretation of the data for the service offered. Also, due to company's culture, the organization's R&D is not open to partnerships. The company's decision is justified on the fear of losing autonomy and also to assure the safety of confidential information. However, such closeness leads to a delayed

decision-making, since employees must constantly adapt to new conditions or learn new skill for each project. Such barriers hinder the development and delivery of proper DPSS, since all knowledge, hardware, and software have to be internally developed before the launch of the DPSS, such as the monitoring and analysis of the paving equipment.

The drivers that led the company to offer such DPSS, according to the interviewees is the search for competitive advantage through the use of data, such as the offer of remote services for maintenance and diagnostics, as a means to anticipate problems, which would add value to the offer. Also, the interviewee mentioned that this relationship enabled by the business model has the potential of developing customer loyalty and later new business opportunities.

4.1.2 Company B: The company is an OEM that builds machines for the production of steel sheets. The machines operate with an operation diagnosis, trying to anticipate failures. Such DPSS is offered as an optional service, charged in the final value of the product. The supplier's staff is responsible for the monitoring of the data.

According the Automation Engineer and the Production Manager, an important barrier for leveraging the data and the remote connectivity is the infrastructure, both the customer's and the country's, since according to the interviewee: *"several customers don't have IT departments, […] and some customers don't even have internet access due to inefficient local structure"* which makes it impossible for them to adopt DPSS offers, even basic ones, such as the diagnosis of failures offered by the company. Also, customers still don't perceive the value in this basic DPSS offer, since they think such service severely increases prices, without recognizing the corresponding benefits. The interviewee complements *"this perception only changes after a serious problem occurs and results in an expensive and unplanned expenditure"*. According to the Production Manager barriers to the adoption also comprehend human-related aspects, because customers need to invest in technical capacitation to users since employees usually lack the capabilities necessary. Another barrier to the adoption mentioned by one interviewee is customers' fear of becoming dependent of the technologies and the services provided, therefore, to avoid such problem, customers tend to internally develop the solutions necessary.

Despite the barriers mentioned, the company interviewees mentioned that the data aspects are important drivers since the capacity of anticipating a problem in a machine and remotely diagnosing these products were the main factors that led the

company to develop the basic-level DPSS offered. As stated by the Production Manager: "*this technology allows us to remotely diagnose our equipment to monitor the status of the components in order to predict maintenance based on the data provided"*.

4.1.3 Company C: The company sells several smart products to industrial applications, such as: optical, inductive, and vibration and temperature sensors. These sensors are connected to a network which allows their characteristics to be monitored, such as: internal temperature, dirt on the lenses, and wear of internal electronic components. Such possibility allows services of alarms for production failures if the equipment's functionality is reduced. These capabilities also enable the monitoring of use and results and these are offered as a service to the customers of the company

According to the interviewees of the company, one of the barriers found for the offer of the DPSS was the lack of subsidies for companies to develop and also to adopt the DPSS solution, given its uncertainty: "*they don't want to invest in something that they don't know if it will work"*, as stated by the Commercial Director. Another barrier related to the value proposition mentioned by the director is the perception of customers that this technology is not necessary: "*the majority of this technology, and the information about it, is imported, which hinders its adoption and makes them think this offer is not suitable for them"*. Another problem related to the international characteristics of DPSS is the risk related to monetary exchange fluctuation which makes investments uncertain. A data-related barrier highlighted by the interviewees is the lack of knowledge about the DPSS operation and how to leverage the data provided by it. In addition, another barrier discussed by the interviewees is employee boycott due to the fear of not knowing how to use a DPSS.

The drivers related to the adoption of the DPSS by the company according to the interviewees was due to its potential of solving problems for the customers, reduce costs and equipment setup, along with increasing productivity. The drivers that led the company to offer this basic DPSS, according to its Director was the increased profit margins provided by the product. Also, interestingly, according to the respondent, cost also led to the development of the DPSS since the investment for such products is not a barrier anymore: "*nowadays, cost is no longer a barrier, since the technology for such products is not much more expensive than regular products*". The interviewees also mentioned that the data in the DPSS offer is an important factor when it was conceived, since, due to its technological nature, DPSS allows traceability of the products, measurement of the efficiency and diagnosis, problem warning, prediction and

prevention. Theses aspects boost the DPSS adoption, according to the director, since the avoidance of problems generates savings, increases efficiency and reduces costs for customers. Also, the DPSS enabled the implementation of add-on services in the customers' operation, such as the sale of engineering services to optimize the setup of the equipment, or to equipment lifecycle assessment. In this sense, we identified that the most important barrier for a basic DPSS, is the lack of value perception by customers. Whereas the most mentioned drivers are related to the use of data and remote access to maintenance and diagnosis and the DPSS adoption.

4.2 INTERMEDIARY DPSS

4.2.1. Company D: The company sells several DPSS offers, the main one being a configurable valve terminal. This system enables the life-cycle monitoring and the performance of the products connected to this equipment, which can trigger alarms with information about the equipment in real time through the monitoring, allowing predictive maintenance. The service attached to this DPSS relies on the data analysis from the machine.

In this intermediary-level DPSS a concern for the offer of the DPSS for predictive maintenance is the need for financing, especially with governmental credit lines with subsidized interests, that aim to develop Brazilian companies, according to the Engineer of Application and the Sales Consultant. The value proposition is also a barrier, according to the interviewee: *"customers do not perceive the value in such technologies because they are not sure it will return their investment in production capacity […] they think that in Brazil it will take a long time before such technology is accepted"*. Another barrier mentioned is the lack of a common communication protocol, since each industry has its own, which hinders the offer of DPSS solutions. The interviewees also mentioned that some customers are not comfortable in sharing their data through the cloud, due to hacking risks, which demands a safe data solution to the provider.

The drivers that led the company to start its investments toward DPSS is the global move toward the adoption of such new concepts, especially in the automotive industry, which will inevitably reach Brazilian industry. In this sense, Brazilian companies are starting to become interested in adopting such services through DPSS due to the increased customization enabled by the technological aspects: *"the industry is being pushed toward more flexible products, with customized aspects, such as the car*

purchase nowadays". Additionally, the increased relationship-based business model leads to an increased loyalty, due to the offer of services attached to the product. Finally, despite the barrier of lack of value perception by customers, according to the findings, a driver to the offer of DPSS is the improved quality, which leads to a better value perception by customers who adopt the DPSS. Moreover, the company identified the possibility of offering DPSS through stages that enables a broader set of customers to adopt them. Finally, a driver mentioned is the possibility of adding an expertise that is not part of the company's capabilities, such as the use of artificial intelligence. The interviewees mentioned that although this is a complex technology, the company was able to add it to their offer given a partnership with a startup. This driver enabled the company to fulfill a growing demand from customers for data services, without necessarily increasing costs.

4.2.2 Company E1: Intermediary DPSS characterized by the offer of printing services (additive manufacturing) with attached services of consulting and modeling for prototypes or batches of products. The DPSS of this company relies on consulting services and assistance for the printing service. The company initially started its operation with a focus on the development and sales of proprietary additive manufacturing equipment. Later, the company started another business focus, selling a European brand of additive manufacturing equipment along with a servitized offer through the sales of printing services with this equipment.

The offer of the DPSS faces barriers because customers' companies are very dependent of governmentally subsidized credit lines for investments in technology which hinders the establishment of constant revenue streams. This factor also represents risks for the provider since the company cannot expect a constant use of the machines since the demand fluctuation is high, this results in equipment idleness and therefore, losses. Also, this problem is related to the high investments necessary, since according to the interviewee: "*to offer such DPSS we have to invest a great amount of money […] and the technologies are expensive*". There are also structural problems that reflect into obstacles to an appropriate offer, due to a bureaucratic and complex import process combined with an unpredictable currency fluctuation. These factors lead to an uncertain business environment in the country. In addition to these factors, in Brazil, there is another local problem of a poor energy infrastructure, that represents problems to the company, which according to him: *"in additive manufacturing, when a machine is printing an object and an energy blackout occurs, all the process already done has to*

be discarded". Finally, according to the company's Director the low quality of supplied material is also a problem that hinders the offer, not only for a DPSS offer but to the company's entire operation. The company also faced barriers due to the lack of knowledge on the provision of services since their main competences were related to product sales.

According to the interviews, most drivers are related to building a closer relationship with customers, as stated by the Director of the company: *"this business model leads to loyalty and more constant business models such as availability-based contract"*. Other drivers of this DPSS are, according to the interviewee: *"the medium-term gains that assure profits in the operation by the business model"* since, due to a time-set contract, this operation leads to profits to the company. This business model works on a 12-month contract, which is enough to cover the costs and lead to a significant profit in the operation. The value proposition aspects of the offer also led the company to offer this DPSS since they can add value to their offer with attached services that deliver more quality to the final offer. It also enables the customers to focus on their core business, instead of making investments or assigning a specific employee to do this job. Additionally, due to the constant monitoring, the company can supervise the use of the equipment to provide preventive maintenance and increase machine uptime. Also, given the provider's know-how on the equipment, the company can offer services to optimize the customer's production as a means to add more income sources. In this sense, in the intermediary level, we identified that the DPSS offer is still a great barrier for the intermediary level, due to contextual problems such as financing and import. However, the most important driver is the value proposition, since companies see an increasing interest for this type of products due to the increased quality they can deliver.

4.3 ADVANCED DPSS

4.3.1. Company E2: Company E2 is another business unit from Company E1. However, this business unit focuses on the provision of an Advanced DPSS in which the consumer contracts the additive manufacturing company through a service with a guaranteed availability contract. To assure the continuous operation, the DPSS provider relies on a remote connection of the equipment, analyzing the operational data and providing consultancy on the operation of the customers and in the machine's maintenance.

According to the interviews, the great majority of barriers faced by the company for the advanced DPSS is related to aspects of the DPSS offer. One of the barriers mentioned was the need to develop the capabilities necessary to offer the services. Also, according to the company Director: "*this type of offer provides less profitability than traditional service models, or even the sale of the product*", additionally the company faced another problem for such offer, the great working capital necessary for the initial offer of advanced DPSS. Such barrier is explained due to the ownership of the equipment belonging to the provider, which demands the company to buy the equipment directly from the machine supplier. Also, customers still do not understand how this business model works, therefore they do not perceive the value delivered: "*this new business model is hard for customers to understand, since they do not see value in the service delivered in it, especially those who have more experience with the equipment and the additive manufacturing specifics (design, product, material, etc.)*". Finally, a barrier mentioned by the Director was that this new offer is more complex and generates a greater dependence by the customer, as stated: "*this product generates more complex contracts, which demands more legal advice"*.

However, despite the risks presented, several drivers were mentioned in this offer. The constant revenues for the provider and therefore the reduced financial risk enabled by this relationship-based business model was mentioned by the Strategy Director, along with the new focus of the company's business model, as stated: "*the company now is specializing in additive manufacturing, instead of the development and sale of products, which enables us to improve our knowledge on this advanced manufacturing system*". Factors related to risks also led the company to offer such service since new technologies of financial transactions (such as cryptocoins) are facilitating such offer. Additionally, according to the director, the company can also leverage this contact with customers and the technology employed in the DPSS to deliver agreed availability contracts for customer's business models and collaborate with these customers, for a closer relationship. The interviewee also mentioned that throughout the whole process of the advanced DPSS development, the company learned more about servitized offers which improved their knowledge for future servitized offers.

The general findings show that the companies identified most barriers for the offer of the DPSS, due to problems such as the expensive technologies related to these products, the problems imposed in the development of these products due to the high

dependence of foreign products or the poor quality of national supply. However, on the drivers' side, the companies pointed that most of the factors that led to the development of this offer is the remote access and use of data enabled by DPSS, since through the technology involved in this offer companies can remotely access equipment, diagnose failures, improve maintenance, etc. Also, according to the drivers' results, the increasing interest on adoption for DPSS is another major driver due to the improved customization and profits among other factors. Therefore, we identified that in general the greatest barrier to a DPSS relies on aspects of its offer and the lack of value perception, whereas the most important driver for companies is the possibilities generated by data and the adoption aspects, which can provide competitive advantages.

5 DPSS FRAMEWORK

Based on the literature review conducted in the DPSS field and on the cases studied, we identified the main dimensions that compose a DPSS in industries. These dimensions represent the components surrounding the DPSS concept and provide a further understanding on the subject. Additionally, it was possible to observe that two perspectives clearly appeared in the case studies, dividing the dimensions into: Organizational Perspective, composed of the dimensions (i) Relationship-based Business Model, (ii) Value proposition and (iii) Risk Management. And the operational perspective, composed of the dimensions of: (iv) DPSS offer, (v) DPSS adoption, (vi) Customer-oriented R&D, and (vii) Remote Access and Data. In the cases analysis we identified that the organizational perspective focuses on strategic aspects of the DPSS, such as how the value offer is delivered, or how close to the customer the business model is. The other perspective is focused on operational aspects and how the services are delivered, the means for the use of data for R&D and the technologies or procedures used to remotely access equipment, monitor or control. The dimensions' relationship is presented in **Table 14** and graphically summarized in **Figure *8*.**

Table 14 - DPSS dimensions

	Definition	**Examples of Drivers and Barriers**
Organizational Perspective	**Relationship-based Business Model** is composed of variables that refer to the relationship between the provider and the customer regarding business transactions, relations, collaborations, new or innovative business models.	**Driver**: stronger customer loyalty (Herterich et al., 2016); **Barrier**: customers' fear of change (Coreynen et al., 2015);
	Value proposition encompasses any variable that refers to the proposition of value, value perception, new uses for the products, lack of understanding of use, etc. Given that DPSS	**Driver**: combined offer with a segmented focus (PORTER; HEPPELMANN, 2015); **Barrier**: difficulty in clearly

	is a rather new concept, the value it proposes and the value it delivers are of increasing interest	communicating the value proposal (Grubic, 2014);
	Risk Management encompasses the exchange of risks between the provider and customers, namely: uncertainties, complexities, novel contracts and other variables that derive from the DPSS relationship and risk outsourcing.	**Driver**: mitigation of risks such as losing contracts due to non-availability (Grubic, 2018); **Barrier**: investment uncertainty (Coreynen et al., 2015);
Operational Perspective	**DPSS offer** encompasses variables specifically related to the offer of DPSS and its stages, such as development, delivery, service provision, gains, necessary capabilities.	**Driver**: improved service capability (Paluch, 2014); **Barrier**: development of totally new competencies and resources (Lerch & Gotsch, 2015);
	DPSS adoption is related to the factors that affect the adoption of DPSS by the customers. These variables address drivers and barriers in the use, adoption, benefits, problems of adopting a DPSS on the customer side, such as the need for financing and the employees' mindset.	**Driver**: highly individualized, customer-oriented solutions (Lerch & Gotsch, 2015); **Barrier**: senior management still holds a product-centric mindset (Grubic, 2014);
	Customer-oriented R&D are the aspects related to the data and information from the DPSS and its use for the development of new products/services, data analysis, better addressing and predicting customers' needs and more accurate product/service introductions.	**Driver**: better understanding of customers' needs (Coreynen et al., 2015); **Barrier**: strong analytic capability to support digitization (Lenka et al., 2017);
	Remote Access and Data refers to the several uses of data for the operations. The use of such data can vary from monitoring, remote access and control, sensing, predictive, proactive and reactive maintenance and repair, error identification and detection, etc.	**Driver**: data for diagnostic and prognostic information about the state of a machine (Grubic & Jennions, 2017); **Barrier**: customers not interested in providing data (Grubic & Jennions, 2017);

Based on the literature and the cases, the developed DPSS framework provides insights on components of the dimensions mostly identified as drivers and barriers in the adoption and offer of DPSS. The resulting framework is shown in **Figure 8**, where the straight lines represent a connection from the provider to the customer, whereas dotted lines represent a flow from the customers to the providers.

The framework presents how each dimension relates to the other. The relations occur directly between the provider and the customer, in an organizational level. For instance, the "risk" flow points from the customer to the provider, as, usually the risk management moves from the customer, in more product-centric offer, to the provider, in more complex and solution-based offer.

Whereas, the operational aspects are mediated by the DPSS since they encompass the services delivered through the use of data for R&D and for the remote access to monitoring and control.

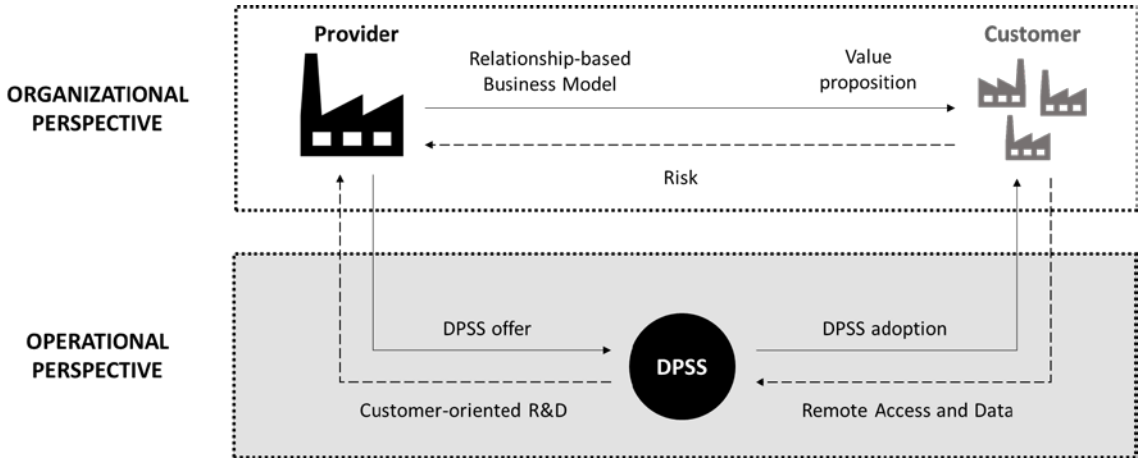


Figure 8 - DPSS framework

It is important to mention that a barrier or driver may belong to more than one construct, that is, the constructs may present overlaps, such as the financial barrier that can belong to the DPSS offer dimension but also to the risk dimension. This is due the integrated offer of DPSS, where not only the product dimension merges with service factors, but also because of the digital characteristic intrinsic to this offer, being subject of overlaps. In these cases, we discussed the better fitting through meetings.

6 DISCUSSION

Based on a framework proposed that builds on previous literature and on the 6 cases analyzed, the major findings drawn from the analysis shows that different drivers and barriers act upon different DPSS levels. Next, we discuss our results considering the findings of this study.

6.1 Organizational Aspects

6.1.1 Value proposition

Initially it is important to highlight the importance of the value proposition to a DPSS offer. Our results show that the value proposition is more mentioned as a driver as the DPSS level increases. This may be explained by the complexity of the offer delivered, since in the basic level the services delivered are more of an accessory than a core part of the offer and business model. Whereas in the intermediary and advanced levels, the DPSS plays a more central role in the offer, thus, customers tend to see a greater quality delivered. This corroborates the findings of Herterich et al. (2016) who show that as the offer focuses on more advanced data analysis, continuous data stream,

increased customer integration and prediction of problems (characteristics that correspond to intermediary and advanced DPSS), the more the provider of the DPSS focuses on the services provided and the delivery value in use, instead of the product. Whereas, in the lowest levels of DPSS, services focus on physical products and value-in-exchange, thus, due to such product-centric focus, the value is not the center of the DPSS offer.

In a complementary view, Belvedere, Grando, and Bielli (2013) found that the relevant impact offered by ICT-enabled service offers occurs when it leads to superior responsiveness of the process and significant improvements in the offer. In such cases, the customer perceives a high value creation by the offer. In this sense, we propose that the lack of value perception is also explained by the lack of significant improvements to the operation permitted by the initial DPSS levels, which hinders an increased value perception by the customers. Whereas in the most advanced DPSS levels, the improvements to the customers' operation, and to the equipment itself are more noticeable, which leads to an increased value perception. Grubic (2018) highlights that DPSS main problem lies on defining the benefits and the gains achieved by avoiding such problems as breakdowns. Thus, DPSS providers must present the benefits of the offer and also how they can affect production, by means of quantitative measures such as mean-time to repair and mean-time to recover. (Kowalkowski et al., 2013). Therefore, we state that, possibly due to its initial phase and research maturity, DPSS still lack measures and variables that accurately.

6.1.2 Risk Management

The responsibility for the risks is an important aspect of DPSS offer and adoption (Grubic & Jennions, 2017), since in the DPSS offer, the business model is highly focused on the customers' transference of risks to providers. Therefore DPSS finds in digitization a means to mitigate risks, such as the use of sensors to monitor performance and predict future conditions (Grubic & Jennions, 2017). Our findings corroborate those of (Grubic, 2018; Grubic & Jennions, 2017) in the sense that the companies report the complexity of the new offer as a DPSS risk, especially offers that involve availability contracts. However, our results show that the use of digital technologies has decreased the risks in offering an availability contract, due to the increased reliability enabled by digitization, such as proposed by Grubic (2018).

In addition, companies reported that another risk is the necessity for high investments to deliver such advanced services, which lead to uncertainties on the return for the investments made. This finding is in line with those of Coreynen et al. (2015) that also mention the need for high investment as a barrier to the DPSS provision in totally new value chains, which shows that this is not an exclusive factor of developing countries.

6.1.3 Relationship-based business model

A business model based on the relationships between customers and providers is a very important part of the DPSS offer, since it generates increased customer loyalty with longer contracts and recurring monetary inflow. However, this driver is more noticed in the most advanced DPSS levels. This fact is due to the closer, collaborative and individualized offer provided in more advanced levels, leading to loyalty and more profits. This is in line the findings of Herterich et al. (2016), who propose such gains in the most advanced level of digitally, enabled services. This type of offer also enables (and supports) the progression to more customized business models oriented to customers' needs, with a higher level of collaboration (Rymaszewska, Helo, & Gunasekaran, 2017). Also, providers can use simpler, less advanced DPSS as a means to lead to the adoption of more complex and advanced DPSS. Therefore companies can follow a maturity path for DPSS levels which are enabled by the successful provision of the earlier DPSS level (Lerch & Gotsch, 2015).

However, companies seeking to adopt this business model must be prepared to face a certain resistance from customers, as our results show that some companies still avoid such closer collaboration for fearing a long-term obligation, which has not been reported in the literature thus far. However, literature indeed mentions a barrier on the other side of the collaboration (from the supplier to the customer), stating that suppliers must integrate customers in the DPSS development process causing it to become a barrier to DPSS providers. This was not found in our results (Coreynen et al., 2015; Lenka et al., 2017). Which shows that despite the necessary collaboration between parties, they still struggle to join forces in DPSS offers.

6.2 Operational Aspects

6.2.1 DPSS offer

DPSS offer plays an important role in strategy, since it encompasses maintenance optimization, employee empowerment, profitability, and the competences necessary to provide this type of product-service system (Herterich et al., 2016). Our findings showed that DPSS offer is seen as the biggest barrier for DPSS, and this can be explained by several reasons. First of all, offering DPSS requires resources, collaborations, and new competences (Lerch & Gotsch, 2015). Interviewees highlighted that developing service and digital competences still hinders the development and support of DPSS, mainly because product companies are only accustomed to selling products. To overcome this barrier, Lerch & Gotsch (2015) state that providers must first identify their current competences and then map the competences necessary to move towards a digitalized offer.

Also, DPSS requires high investments and the equipment necessary are usually imported. Bureaucracy to import and the lack of credit lines are highlighted by the participants as barriers from the context of Brazilian industrial and innovation setting, which is in line with previous studies on innovation in Brazil (Frank, Cortimiglia, Ribeiro, & de Oliveira, 2016), nevertheless, it has never been pointed out in DPSS literature.

DPSS offer is also hindered by infrastructural problems. Although this has been previously documented in studies that address the DPSS need for internal IT infrastructure, our findings shed light on the specific barriers of the Brazilian context, both overall infrastructure and internal infrastructure. Jitpaiboon *et al.* (2013) highlight that provider's good IT infrastructure is mandatory for the successful offer and support of DPSS. Grubic and Jennions (2017) highlight that suppliers also need a network infrastructure to allow data sharing and acquisition. We found that this internal infrastructure for DPSS is mostly influenced by the interface of suppliers, customers, and third-party actors. Suppliers must design solutions that fit into the customers standards. Whereas, most of the times customers need to update old networks and invest in new IT equipment to reach a minimum data network infrastructure that handles and communicates with the suppliers' IT infrastructure. Finally, third-party actors must provide the necessary means for DPSS support which include high uninterrupted power supply, high speed stable connections, and reliable cloud infrastructure to cloud storage and cloud computing.

6.2.2 DPSS adoption

DPSS adoption is also hindered by the digital infrastructure of the customer company which must update equipment to be able to leverage from the benefits provided by DPSS. Additionally, DPSS adoption was found to be boycotted by employees due to their fear of using it, which was not reported in previous literature. This barrier is closely related to the lack of digital competences of companies and employees. When employees do not speak or comprehend the value delivered they tend to boycott the DPSS because they are not able to perceive the benefits or productivity gains.

Although some barriers were reported by respondents, DPSS adoption is mostly perceived as a driver because it enables problem-solving and problem visibility. Also, other drivers highlighted by respondents were identified, such as: increased productivity and reduced equipment setup. This is in line with the findings of previous authors that reported the potential gains of DPSS adoption. Grubic (2018) for example highlighted the decrease in operating costs of DPSS adoption, and Coreynen et al. (2015) found that DPSS reduce lead time.

6.2.3 Customer-oriented R&D

Customer-oriented R&D is mentioned several times as an important dimension in literature. Rymaszewska, Helo, & Gunasekaran (2017) highlight that data derived from operational sources can be used for R&D purposes, and it can even be commercialized with third-party actors, whereas Lenka et al. (2017) proposes that it can be used as a value co-creation mechanism by predicting customers' needs using data from the equipment. Although there are large possibilities of building closer relationships with customers by providing DPSS that meet their demand more satisfactorily, only one interviewee mentioned customer-oriented R&D which goes the other way from literature. In fact, the only respondent to mention this factor was in the basic level and this may provide evidence that this is still an incipient advantage perceived by companies in Brazil. Explanations may lie in the fact that companies have not reached the necessary skills and maturity necessary for this use of DPSS information, or they are not aware of the possibilities because of the still early adoption of DPSS. Therefore, these advantages would just reveal themselves as companies gain

ground on this type of offer and as they grasp more possibilities of increasing value through the data.

Lerch & Gotsch (2015) also mention this advantage as an important aspect to the DPSS provider since it enables faster innovation cycles and allows products to become more automated and independent through upgrades. However, the cases in the intermediary and advanced levels of our study do not mention such use of the data which highlights that companies that could leverage such capabilities still fall behind. Since DPSS in these more advanced levels are more focused on remote access and data to enable more advanced BM, they may overlook the strategic drivers of using data to feedback R&D, that is, they are more focused on the operational uses of data (remote access and data), than its strategic (long-term) uses (customer-oriented R&D).

6.2.4 Remote Access and Data

Drivers of remote access and data encompass benefits such as the constant monitoring and the increased knowledge about the equipment's performance, which is line with the proposed by Grubic and Jennions (2017). However, customers fear the safety and confidentiality of their data which hinders their willingness to share information. Possible explanations to customers' fear of data exchange are the inconsistency in data collection and hacking possibilities (Grubic & Jennions, 2017; Porter & Heppelmann, 2015). Additionally, we found that the possibility of human misinterpretation of data in another relevant barrier. Previously, Grubic (2014) had stated that technology can be a source of errors and it can misinterpret complex and rich data. Nevertheless, the human aspect has not been portrayed in DPSS literature and it is connected to the lack of data analysis competences of both the provider and the customer company.

Another cultural aspect that works as barriers to remote access and data is the customer company's closure to external partnerships and collaborations, which impacts data exchange and how open the customer company is to changing processes based on the insights of the data collected. This is in line with what has already been reported by Coreynen et al. (2015), Porter and Heppelmann (2015), and Paluch (2014).

6.3 DPSS Levels

6.3.1 Basic DPSS

The basic DPSS is a level focused on the delivery of simpler, more reactive services, therefore, as it can be seen in the results, the drivers and the barriers for this level are mostly related to operational aspects of the offer, since the value is delivered in this part of the offer. In this sense, our results show that the main barriers follow such logic, since they are more related to the DPSS operational aspects and contextual characteristics that affect it, instead of business model or risk problems. Basic level characteristics also explain value proposition barriers found. This level is usually characterized by DPSS suppliers' perception that customers do not see the value of such offer. This can be explained by cultural aspects, such as the lack of knowledge on such incipient theme in Brazil. Also, such level only provides incremental enhancement to the traditional, human-centered, maintenance, repair and overhaul activities, which focus on the value of exchange instead of value-in-use (Herterich et al., 2016). Therefore, DPSS providers should focus on improving the gains of this offer by adding complementary services to the monitoring activities to improve final offer toward a more holistic and complementary package, instead of the current standalone, product-centric view.

As for the main drivers for this DPSS level, we identified that our results are in line with the value proposition of the basic level, which is the provision of monitoring and control service, therefore, as expected, the main drivers for this level are the possibilities enabled by the remote access and data arising from the technology employed. Such finding agrees with most of the DPSS-related literature, such as the findings from Lerch and Gotsch (2015) that state that this capabilities allow providers to avoid breakdowns, improving maintenance, tests and verification, and constant assistance. An evolution to this services is proposed by Herterich et al. (2016) that identified cases where the machines report errors by themselves, without human intervention. This automation can lead the development of high service levels, such as an Intermediary DPSS.

6.3.2 Intermediary DPSS

In this level, the value is more attractive to customers since they can identify the improvements proposed by the data analysis. The optimization provides competitive advantages to customers, which is also mentioned by Lerch and Gotsch (2015). Also, according to the results of our cases, this service enables more ways to deliver other

services and add value, leading to more profits, which was corroborated by Lerch and Gotsch (2015).

Barriers in this level are focused on the DPSS offer and the Risk Management for such offer. In the DPSS offer, the point of most concern is focused on financial and structural aspects. This is in line with Coreynen et al. (2015) that state that the investments necessary are a barrier. Risk is another major barrier, according to our results, due to the complexity of the offer, demanding more investments to uncertain returns. This may be explained due to customers' culture, since customers associate this type of service with an increased level of risks, due to its digitization and complexity (Paluch, 2014),.

The drivers also differ from those from the basic level since in this level the value proposition is an important driver for the DPSS offer. This is due to the possibility of adding value to the offer with complementary services, and the fact that customers see a higher value since they can focus on their core business, while the DPSS provider is in charge of operational aspects.

6.3.3 Advanced DPSS

The case studied of advanced DPSS shows that the barriers in the organizational aspect of DPSS is the lack of knowledge of such advanced offers by customers, which is complemented by the lack of value perception by customers with an experience in the equipment operation, since they do not need the services delivered by the consulting services attached to this DPSS level. Also, despite the increase of risks in such advanced offer due to the more complex contracts, the opposite was also found, since due to the technology employed there are fewer risks to offer more advanced business models such as availability guarantees.

However, the drivers found solely belong to organizational aspects of the offer, due to the advanced DPSS focus on a more complex and customized business model, which leads to better offers that improve the quality of the services to customers and, according to our results and those of Herterich et al (2016), generate constant revenue streams, with reduced risks, due to the technology applied (Grubic & Peppard, 2016). These findings were also mentioned by Lerch and Gotsch (2015) who state that in this level, not only the physical, but also the intangible parts of the DPSS are improved, which can lead to a longer partnership with customers, toward a stronger loyalty (Herterich et al., 2016).

7 CONCLUSION

7.1 IMPLICATION FOR THEORY

This study addressed a literature gap not fully approached yet, namely the identification of barriers and drivers for the offer and the adoption of DPSS, in the organizational and the operational perspectives. Building on that, we provide insights on both general aspects and specificities that arise in a DPSS offer in developing countries. Our findings add to those of literature in the sense that no other study has structured and systematized the DPSS dimensions, their drivers and barriers. In this sense, we identified that the DPSS context is composed of seven dimensions: risk, value proposition, relationship-based business model, DPSS offer, DPSS adoption, remote access and data, and customer-oriented R&D. Thus, we analyzed how each of the dimensions affect the DPSS levels. The main theoretical contributions of this study are the framework proposed for a DPSS analysis which can be used to replicate studies in this field. Also, another important contribution is the findings on each DPSS level, such as: in the basic level the companies identify more operational barriers and drivers due to their high focus on the operation. However, as the DPSS level increases, companies tend to perceive more drivers in the organizational aspects of the offer, since the business model and the value offer rely on more complex activities, that increase the value perception and consequently the income and loyalty.

7.2 IMPLICATIONS FOR PRACTICE

Our findings show that companies offering the basic level DPSS experience more barriers related to remote access and data, since the necessary capabilities to offer such technology-enabled service are not common. However, this factor is the most mentioned as a driver to offer basic DPSS, since it enables new value delivering ways. The intermediary level presents most barriers in the offer, due, mostly, to contextual factors such as difficulties in importing, lack of financing and the price of such technologies. Finally, the advanced level also shows barriers for the offer, since companies must develop a set of capabilities that are hardly seen in manufacturing companies, due to the complexity of the offer. The drivers of this level show that the technology has an important role in reducing risks, since it enables a constant monitoring and predictability for availability contracts.

7.3 LIMITATIONS AND SUGGESTION FOR FUTURE RESEARCH

This study faces some limitations such as it is qualitative in its approach, which precludes the findings here exposed from being generalized to the whole DPSS context, or even other developing countries. In this sense we suggest future studies to provide further insights on the dimensions that are identified as barriers and drivers in other economic contexts, such as developed economies as a means to improve the knowledge on this field, specially through quantitative works.

Also, future studies should research on how to overcome the barriers identified in this article, especially the most problematic aspect of DPSS, value proposition. Therefore, researchers should study how to better disclose and show the value proposition of the offer. Studying the attributes valued by the customers can bring important insights for a more valuable DPSS offer. Also, research should identify how to actually harness data to improve products and services based on the feedback and data collected into customers environment, since few studies have been conducted in this area.

REFERENCES:

Akaka, M. A., & Vargo, S. L. (2014). Technology as an operant resource in service (eco)systems. *Information Systems and E-Business Management*, *12*(3), 367–384. https://doi.org/10.1007/s10257-013-0220-5

Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production*. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2016.08.061

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Ruggeri, C., Ardolino, M., … Gaiardelli, P. (2017). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *7543*(May), 0. https://doi.org/10.1080/00207543.2017.1324224

Ardolino, M., Saccani, N., Gaiardelli, P., & Rapaccini, M. (2016). Exploring the Key Enabling Role of Digital Technologies for PSS Offerings. *Procedia CIRP*, *47*, 561–566. https://doi.org/10.1016/j.procir.2016.03.238

Ayala, N. F., Paslauski, C. A., Ghezzi, A., & Frank, A. G. (2017). Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *International Journal of Production Economics*, *193*(August 2016), 538–553. https://doi.org/10.1016/j.ijpe.2017.08.019

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., … Wilson, H. (2007a). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. https://doi.org/10.1243/09544054JEM858

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., … Wilson, H. (2007b). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. https://doi.org/10.1243/09544054JEM858

Belvedere, V., Grando, A., & Bielli, P. (2013). A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system. *International Journal of Production Research*, *51*(2), 410–426. https://doi.org/10.1080/00207543.2011.648278

Bouwman, H., Carlsson, C., Molina-Castillo, F. J., & Walden, P. (2007). Barriers and drivers in the adoption of current and future mobile services in Finland. *Telematics and Informatics*, *24*(2), 145–160. https://doi.org/10.1016/j.tele.2006.08.001

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, *13*(1), 3–21. https://doi.org/10.1007/BF00988593

Coreynen, W., Matthyssens, P., & Van Bockhaven, W. (2015). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Industrial Marketing Management*, *60*, 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*(December 2017), 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: opportunities and challenges diverse. *Academy of Management Journal*, *50*(1), 25–32. https://doi.org/10.1002/job.

Frank, A. G., Cortimiglia, M. N., Ribeiro, J. L. D., & de Oliveira, L. S. (2016). The effect of innovation activities on innovation outputs in the Brazilian industry: Market-orientation vs. technology-acquisition strategies. *Research Policy*, *45*(3), 577–592. https://doi.org/https://doi.org/10.1016/j.respol.2015.11.011

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*(January), 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Grubic, T. (2014). Servitization and remote monitoring technology. *Journal of Manufacturing Technology Management*, *25*(1), 100–124. https://doi.org/10.1108/JMTM-05-2012-0056

Grubic, T. (2018). Remote monitoring technology and servitization: Exploring the relationship. *Computers in Industry*, *100*, 148–158. https://doi.org/10.1016/j.compind.2018.05.002

Grubic, T., & Jennions, I. (2017). Remote monitoring technology and servitised strategies – factors characterising the organisational application. *International Journal of Production Research*, *7543*(May), 1–17. https://doi.org/10.1080/00207543.2017.1332791

Grubic, T., & Peppard, J. (2016). Servitized manufacturing firms competing through remote monitoring technology An exploratory study. *Journal of Manufacturing Technology Management*, *27*(2), 154–184. https://doi.org/10.1108/JMTM-05-2014-0061

Herterich, M. M., Uebernickel, F., & Brenner, W. (2016). Stepwise Evolution of Capabilities for Harnessing Digital Data Streams in Data-Driven Industrial Services. *MIS Quarterly Executive*, *15*(4), 297–318. Retrieved from http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=bth%7B&%7DAN=120565633%7B&%7Dsite=ehost-live

Jitpaiboon, T., Dobrzykowski, D. D., Ragu-Nathan, T. S., & Vonderembse, M. A. (2013). Unpacking IT use and integration for mass customisation: A service-dominant logic view. *International Journal of Production Research*, *51*(8), 2527–2547. https://doi.org/10.1080/00207543.2012.720727

Kowalkowski, C., Gebauer, H., & Oliva, R. (2017). Service growth in product firms: Past, present, and future. *Industrial Marketing Management*, *60*, 82–88. https://doi.org/10.1016/j.indmarman.2016.10.015

Kowalkowski, C., Kindström, D., & Gebauer, H. (2013). ICT as a catalyst for service business orientation. *Journal of Business & Industrial Marketing*, *28*(6), 506–513. https://doi.org/10.1108/JBIM-04-2013-0096

Lenka, S., Parida, V., & Wincent, J. (2017). Digitization Capabilities as Enablers of Value Co-Creation in Servitizing Firms. *Psychology & Marketing*, *34*(1), 92–100. https://doi.org/10.1002/mar.20975

Lerch, C., & Gotsch, M. (2015). Digitalized Product-Service Systems in Manufacturing Firms : A Case Study Analysis Digitalized Product-Service Systems in Manufacturing Firms, *6308*. https://doi.org/10.5437/08956308X5805357

Lightfoot, H., Baines, T., & Smart, P. (2013). The servitization of manufacturing. *International Journal of Operations & Production Management*, *33*(11/12), 1408–1434. https://doi.org/10.1108/IJOPM-07-2010-0196

Mani, Z., & Chouk, I. (2016). Drivers of consumers' resistance to smart products. *Journal of Marketing Management*, *00*(00), 1–22. https://doi.org/10.1080/0267257X.2016.1245212

Marcon, É., Marcon, A., Ayala, N. F., & Frank, A. G. (2019). Digital product-service systems: a literature review on the convergence between servitization and digitization. *Working Paper*.

Opresnik, D., & Taisch, M. (2015). The value of big data in servitization. *International Journal of Production Economics*, *165*, 174–184. https://doi.org/10.1016/j.ijpe.2014.12.036

Pagoropoulos, A., Maier, A., & McAloone, T. C. (2017). Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry. *Journal of Cleaner Production*, *166*, 369–380. https://doi.org/10.1016/j.jclepro.2017.08.019

Paluch, S. (2014). Customer expectations of remote maintenance services in the medical equipment industry. *Journal of Service Management*, *25*(5), 639–653. https://doi.org/10.1108/JOSM-07-2013-0195

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies The. *Harvard Business Review*, *1*(November).

Porter, M., & Heppelmann, J. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, *92*(11), 64–88.

Rijsdijk, S. A., & Hultink, E. J. (2009). How today's consumers perceive tomorrow's smart products. *Journal of Product Innovation Management*, *26*(1), 24–42. https://doi.org/10.1111/j.1540-5885.2009.00332.x

Rijsdijk, S. A. S. S. A. S., Hultink, E. E. J., & Diamantopoulos, A. (2007). Product Intelligence: Its Conceptualization, Measurement and Impact on Consumer Satisfaction. *Journal of the Academy of Marketing Science*, *35*(3), 340–356. https://doi.org/10.1007/s11747-007-0040-6

Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics*, *192*, 92–105. https://doi.org/https://doi.org/10.1016/j.ijpe.2017.02.016

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, *22*(2), 195–219. https://doi.org/10.1108/01443570210414329

Yin, R. K. (2003). *Case Study Research*. *Sage Publications* (Vol. 5). Retrieved from http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00003727-201110000-00014

Yoo, Y., Boland, R. J., Lyytinen, K., & Majchrzak, a. (2012). Organizing for Innovation in the Digitized World. *Organization Science*, *23*(5), 1398–1408. https://doi.org/10.1287/orsc.1120.0771

5 FINAL CONSIDERATIONS

This section aims to provide a final summarization of the findings from the articles as well as to show how each article builds on the results from the former to reach the objective of this dissertation.

5.1 CONCLUSIONS

Aiming to increase the knowledge on the interface between digitization and servitization this dissertation addressed this objective through three separate, yet complementary, studies. The literature on the field shows several gaps which were addressed in this dissertation. The studies are organized in an order from a more generic, broader scope to a more specific, detailed analysis. That is, the first article addresses a more generic problem, which is the barriers identified by managers and researchers and consultants in the use of digitization for the innovation process and in the innovation outcome of servitized offers. Therefore, in this study the first specific objective was approached, namely: To identify the barriers of digitization in the innovation process and the use in the innovation outcome of servitized offers. Our results showed that in the innovation process, the barriers are more related to operational aspects, such as financial and data security, and also human resource aspects, such as the competences necessary. Whereas, the outcome barriers focus more on strategic aspects, such as market acceptance, short-term vision, and market acceptance. Finally, building on the results obtained, we opted to further analyze the use of digitization to the innovation outcome in the next chapters, since it impacts directly on the final result and it directly affects customers' value perception. Also, our choice was based on an analysis of the type of barriers found, since outcome barriers are more complex and profound, whereas in the innovation process the barriers were mostly related to contextual aspects, such as the companies' financial characteristics, the competences necessary and the resistance to changes, which usually refer to operational obstacles.

The second article addressed DPSS levels and the digital capabilities necessary to deliver each DPSS level through a systematic literature review. Our results show that four variables compose a DPSS offer, namely: risk management, business model, type of service provided, and data use. These variables differ in intention and complexity as the DPSS level changes from basic to advanced. Our findings show that the set of

capabilities necessary to the offer of each level builds on the set of capabilities from the previous level. Also, we show that in the most advanced level, a wide set of digital capabilities are necessary, which increases the complexity of this offer. We also identified that the most basic DPSS levels are more related to a service complementing a product logic, whereas in the most advanced level, the service aims at substituting the offer of the product.

The last article sought to identify the barriers and drivers for DPSS offer and adoption, and to understand Brazilian contextual aspects and the differences with the theoretical state-of-the-art. Based on the DPSS levels proposed in Chapter 3 (Article 2), we found that contextual barriers are still an important barrier to the DPSS offer and adoption, since Brazil still suffers from structural problems, such as electricity blackouts, importation bureaucracy, and exchange rate variation. This article still proposes an important framework of analysis that addresses the several variables that encompass DPSS, through both the offer and adoption points-of-view.

Grounded on these results this dissertation sought to increase the knowledge on the intersection between digitization and servitization through an in-depth analysis of the DPSS offer. In this sense we provided an in-depth analysis of how DPSS providers may leverage the digitization of their offer as a means to increase the value delivered in services, customer loyalty, revenues, and also the knowledge on customers' patterns of use and value perception.

Our findings show that literature still has several topics to address in the DPSS field, given that the servitization field has been widely studied but the addition of digital technologies to its delivery brings a set of challenges and new opportunities yet to be discovered. Our studies show that the majority of the propositions for the use of DPSS are still focused on solely maintenance aspects, whereas, more innovative approaches are still being conceived such as the use of the DPSS for consulting, optimization of the production or even to product development.

5.2 Suggestion for Future Studies

Future research should address aspects that this dissertation could not focus due to our scope definition and/or time limitation. In this sense we identified that current literature still has not satisfactorily approached the requirements necessary for the delivery of DPSS to different sectors of the industry, since a widely mentioned barrier in both literature and our results point to the lack of value perception by the customer as

a problem to DPSS adoption. In this sense, a study analyzing the segments of industry and their demanded requirements could provide further insights on how to better address the value demanded by each industrial sector.

Additionally, further studies could address how to better develop DPSS through a collaboration between customers and suppliers, which could lead to benefits to both sides, since suppliers can leverage the knowledge obtained in this endeavor, whereas customers achieve a customized solution to their needs. Thus, a collaboration between both parties has the potential of bringing advancements in the literature on knowledge sharing dynamics in the DPSS development.

Future studies could also verify the drivers and barriers proposed in the third article of this dissertation in the context of developed economies, which could provide a different view on the aspects related to the DPSS offer and adoption, since not only local factors affect the offer, such as financial problems or importation bureaucracy, but also problems such as the lack of perception of the benefits or the difficulty in product operation.

We also propose studies to provide more quantitative analysis, since the main approach employed in this field has been qualitative. Therefore, quantitative studies could provide generalizable insights, since the current maturity of the field demands more descriptive methods. In this sense, we suggest studies to quantitatively validate the DPSS levels framework proposed in article 2, as a means to increase the knowledge on each DPSS level but also other aspects that compose this offer.