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

Porto Alegre

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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.

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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.

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

Isaac Newton

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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 capacidades 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 capacidades 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 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.

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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.

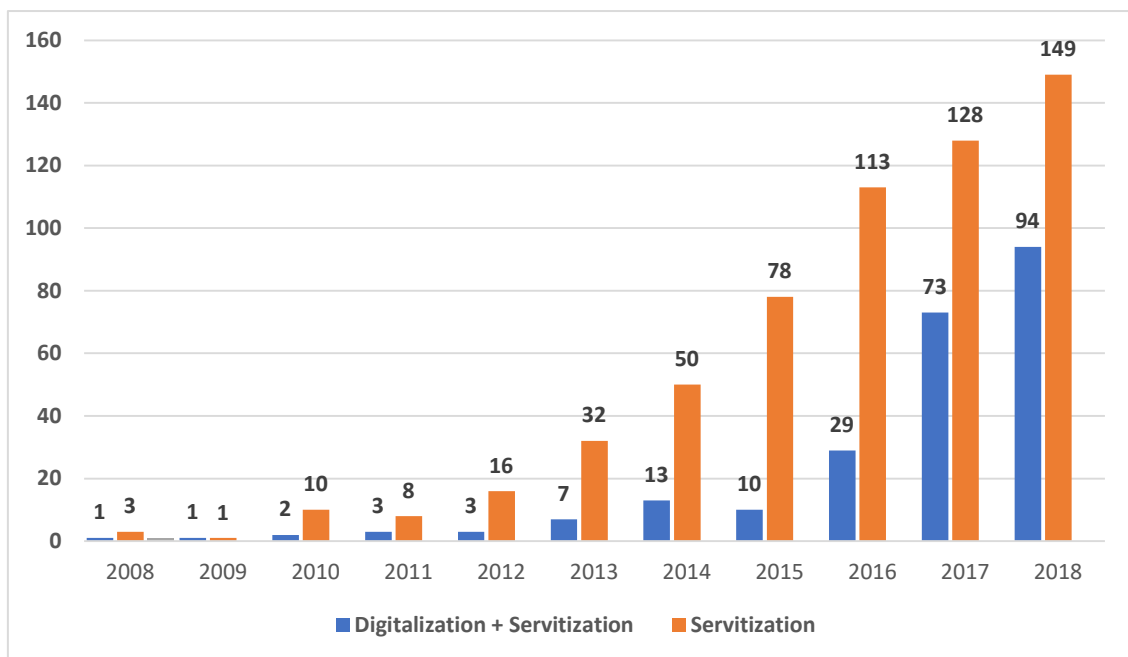


Figure 1- Digitization and servitization research field

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 *to 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 *to 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, Tsiriktsis, & 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.

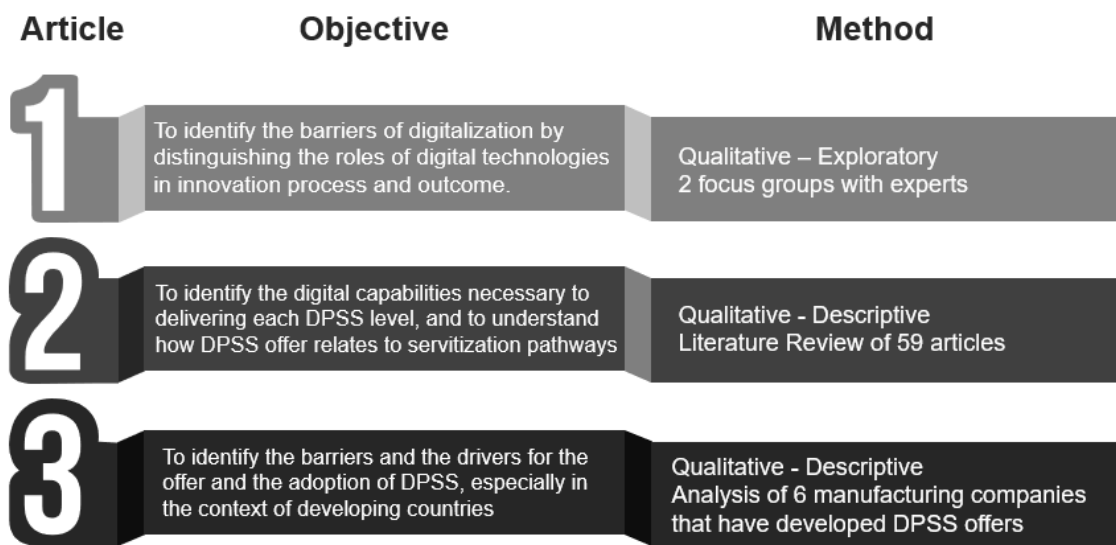


Figure 2 - Summarization of the objectives and methods employed in the dissertation

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.

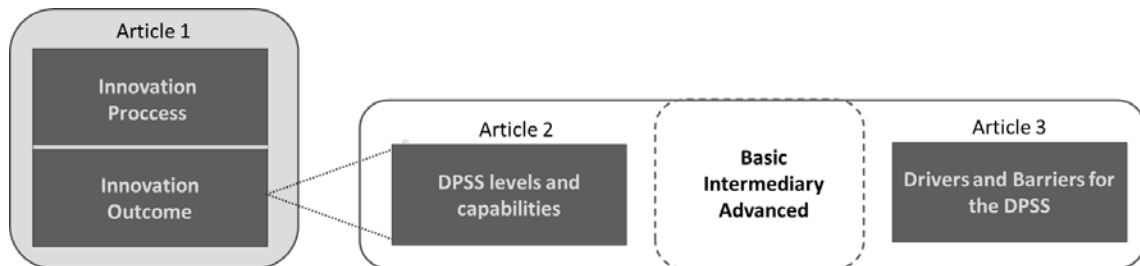


Figure 3 - Articles' connection through the structure of the dissertation

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](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., Tsiriktsis, 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 SERVICITIZATION

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

Table 7 - Ranking of digitization barriers for innovation outcome

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

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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., & McAlloone, 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, connected 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>

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.