Digital Capabilities to Support Digital Product-Service Systems

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Abstract

The advent of digital technologies enabled new Product Service Systems (PSSs) grounded by digital capabilities, i.e. digital PSS. Although the literature has already begun to explore some cases of PSS offerings supported by digital technologies, it remains a considerable gap about the role of digital capabilities in new PSS solutions provided by product firms. In this context, the purpose of this study is to answer the important question: how digital capabilities support different types of PSSs? Following Cusumano's et al. (2014) division of PSS offerings according to the role of service, i.e. smoothing, adapting and substituting, we conducted interviews in Brazilian companies representing these types of PSS. These cases were selected because the PSS offerings were supported by digital technologies. Our findings show that the digital capabilities can have different implications in PSS and that their im-portance variates according to the role of services in adding value to the digital PSS offering. Particular-ly, product monitoring digital capabilities were highlighted as relevant for all types of PSSs, while optimization and autonomy digital capabilities were stated as important only to higher value-added offers.

Keywords
Digital capabilities, Product service systems, Servitization, Digitization and Collaboration.

1. Introduction

Nowadays, there is a tendency of manufacturing firms to offer integrated solutions of products and services to their customers, instead of just products (Colen and Lambrecht 2013). This has been done to provide more complete value offerings to the clients (Baines et al. 2011; Visnjic Kastalli and Van Looy 2013). This movement it's called "servitization" for Vandermerwe and Rada (1988), which results in Product Service Systems (PSSs). These systems are defined as a business model in which services are incorporated to a tangible product, traditionally offered by manufacturing firms, and has the pur-pose to provide the customers a bundle of goods, support services and knowledge that better meet their needs (Baines et al. 2017).

In the past years, with the cost reduction of sensors and cloud technology, PSS solutions were disseminated through digital technologies, allowing the monitoring, storage and analysis of data (Marilungo et al. 2017). The ICT dissemination allowed the development of more advanced service layers, providing new connectivity and smart capabilities (Enrique et al. 2018; Fetterman et al. 2020; Ayala et al. 2020). These solutions are called "digital service solutions" (DSS), and they are delivered through a connected platform with digital transactions of in-formation, software or goods, based on the Internet of Things (IoT) concept (Marilungo et al. 2017; Marcon et al. 2019). The digitization is quickly redirecting industries and economies, allowing new PSS that transforms customer-supplier relationships and introduce new value propositions (Pagoropoulos et al. 2017; Ayala et al. 2019). However, this transformation generates a big impact in the companies' business models, bringing challenges in many strategic and operational aspects (Alghisi and Saccani 2015; Adrodegari et al. 2017; Marilungo et al. 2017).

In this context, authors like Ardolino et al. (2017) and Rymaszewska et al. (2017) indicate that the digital technology role in the service business transformation is still poorly researched, suggesting further studies that better analyze how digital capabilities support the development of digital PSS. Considering this, an important research question appears: *How digital technologies are used according the different digital PSSs?* To answer this question, this paper aims to describe four case studies of digital PSS development in Brazilian companies, identifying the digital capabilities that allowed their development. Through semi-structured interviews, we collect the feedback of CEOs and managers, which classified the digital capabilities in their offerings as little important, important and very important. We complement our findings with discussions about the strategies pursued by the companies and how they develop the necessary digital capabilities.

2. Theoretical background

Servitization, according to Vandermerwe and Rada (1988), is the value creation of the product by means of service addition, resulting in product service systems (PSSs). Through these systems, manufacturing firms seek to offer the client a complete bundle of goods, support services, self-services and knowledge (Baines et al. 2011; Visnjic and Van Looy 2013; Paslauski et al. 2016). The PSS can be offered in many variations, in which several studies aimed for such categorization (Coreynen et al. 2016). In the framework of Cusumano et al. (2014), which identifies different types of PSS offerings according to the manufacturing firms' competitive strategy, services offerings are divided in two main groups: complementary ser-vices or substituting services. Complementary services can be subdivided in: (i) smoothing services, which ease the sale or use of the product without altering the product functions; (ii) adapting services, which are integrated to the product and extend product functions (Paslauski et al. 2017). In substituting services, products are the background of the offering, with focus on the service. In order to reach this kind of offering, a radical change of the companies` business model becomes necessary, with several inherently challenges in strategical and operational aspects (Alghisi and Saccani 2015).

One solution found by the companies to support their business model transformation has been the application of digital technologies (Coreynen et al. 2016; Pagoropoulos et al. 2017; Benitez et al. 2020). Digital technologies, such as the internet of things (IoT) concept, cloud computing, big data and predictive analytics, can connect people, systems, companies, products and services within the digitization concept (Coreynen et al. 2016; Tao et al. 2018). Through its capacity to capture and share data, IoT can be integrated in any service transformation strategy, including the support in new ways of payment through the identification, tracking and time registration of product usage (Ardolino et al. 2017). If the offering is performance-oriented, IoT can be combined with cloud computing and predictive analytics to collect field data and make predictions about product failure and customer behavior, as in such case the company needs to monitor its service to reach the desired performance. Therefore, these technologies can enhance the management of operations with the provision of digital service solutions (Marilungo et al., 2017), overcoming some challenges of the service transformation in PSS (Coreynen et al. 2016).

In such context, digital PSS are developed, in which digital services and physical products become more integrated, resulting in more advanced offerings (Coreynen et al. 2016; Rymaszewska et al. 2017). This type of PSS can increase the value perceived by the customers, reduce entry market barri-ers and optimize operations, but demands new

capabilities that can be a challenge for manufacturing firms (Coreynen et al. 2016). So far, literature describes digital PSS with capabilities that are able to: (a) identify the product and the user; (b) monitor product/process status and condition; (c) to situate where the product is through geolocation; (d) control and personalize the product functions; (e) make product behavior predictions through predictive analysis; (f) optimize the product/process perfor-mance; and (g) develop autonomous products (Ardolino et al. 2017; Marilungo et al. 2017; Porter and Heppelmann 2014; Rymaszewska et al. 2017). These digital capabilities enable digital PSS with more advanced service layers, such as the case of Canon, which developed a cloud platform that connects machines and monitors its status, ink level, and failure events, improving its maintenance service with no need of on-site technical visits (Ardolino et al. 2017). The case of Canon and other case studies de-scribed by Ardolino et al. (2017) and Coreynen et al. (2016) evidence how digitization enables different servitization strategies, according to the operational strategies of the companies. However, more case studies must be conducted to understand how digital PSSs can benefit from the plethora of ap-plications of digital technologies.

3. Method

We conducted an empirical research in order to understand how digital technologies are used according to the different types of digital PSS solutions. For this, our research is based on qualitative data analysis of case studies, conducted in large multinational companies located in Brazil.

3.1 Selection and sample characteristics

The case studies were selected by means of theoretical sampling, as they provide a clear comprehension of the studied phenomenon. We selected four manufacturing firms that offer digital PSS solutions through digital technologies. The information about each firm is shown in Table 1.

TABLE 1. Sample characteristics

Company	Description	Interviewee
Case A	Energy, automation and medical equipment multinational company	Business developer
Case B	Dental/medical equipment multinational company	CEO in Latin America unit
Case C	Multinational company in the segment of elevators	Services project manager
Case D	Building and residential automation company	CEO

3.2 Method for data collection and analysis

We investigated the feedback from managers and CEOs about the digital PSS developed in their companies. This data was collected through semi-structured interviews, with an average duration of 45 minutes. All interviews were recorded and subsequently transcribed. In addition, notes were taken by the researchers during the interviews and other information was collected and triangulated from the companies` websites. The interviews were conducted in two steps: first, the understanding of which products and services a given company offers and the identification of its customers. Secondly, the understanding of how the services were provided with the products through digital capabilities and how these were obtained.

4. Results

In this section, we described the four case studies according to the conducted interviews. In each case study we address the reason for the digital PSS development, how digital capabilities enabled such development and which technologies were necessary.

4.1 Case A

The Company A was a traditional developer and manufacturer of technologies for electric energy generation, industrial and building automation, medical equipment, railway vehicles, water treatment plant systems and more. The company started to offer different services, such as maintenance, extended warranty, energy consultancy and complete solutions of energy as engineering studies, field services, equipment upgrade and projects for efficiency and sustainability. Our

case study is focused in the plant management offering, which can be considered a substituting PSS. Regarding the digital technologies level of the offering, the interviewee mentions the high technological level of the company, which since 2009 has been acquiring companies specialized in digital solutions and also in Industry 4.0 concepts. In 2017, the company launched its cloud platform in MindSphere, in order to connect all its products and collect equipment data. The data is then used to redesign products or displayed to the customer. This platform supported some PSS solutions offered by the company, as the energy service pack. With the Transition Minimized Differential Signaling (TMDS) and smart monitor system for remote monitoring, this pack is capable to diagnose and make predictions about the energy consumption. Furthermore, these technologies can collect real time data of the products that supports maintenance services. With the real time information, the service sector of the company monitors the equipment and, when a failure is detected or predicted, the company schedules the necessary correction with its customer. Information about the product user and location is important to make comparisons among different products offered and the behavior of the same product in different conditions. To develop such capabilities, even with high investments in its R&D department for a technological upgrade, the company had to acquire technology suppliers and to make partnerships with startups and other companies, e.g. SAP for the cloud platform.

4.2 Case B

The second case study is a global leader company in dental equipment and diagnoses systems. The company, with headquarters and research and development sector in Germany, attempted to enter the Brazilian market, but faced some barriers once the customer needs in Brazil were different than the other markets supplied by the company. Unlike in Germany, orthodontists in Brazil usually use printed dental radiographies developed by chemical products. This culture is sustained by requirements of the public health care system in the country. Once the German digital dental scanner makes a digital radiography of the patients, a simpler process but with no development of a printed radiography, the company had to make an adaptation through a software that generates a physical copy of the digital radiography, even allowing the printing of several images in the same radiography. They started to offer a sale contract of the software along with the digital scanner. The software has no cost for the orthodontists in the first year of usage, period of the warranty of the equipment. In the subsequent years of utilization, the company charges for the usage of the software, possibly with remote monitoring and the development of fault diagnosis reports of the equipment, according to the contract chose by the orthodontists. This PSS solution can be classified as Adapting Services, once it expands the product functions. Furthermore, the company also uses the TeamViewer software for technical support, which enables the remote training for installation of the digital dental scanner and its usage instructions. With this software, the company significantly reduced costs by cutting off on-site trainings.

According to the interviewee, the most relevant digital capabilities to develop the solution were the product and user identification, product performance monitoring, remote connectivity and control. The software was developed by a partnership between the company and a supplier, once the Brazilian market had a specific need. The support service of the software to the orthodontists was offered only by Company B, except for a few software failures in which the supplier provides assistance through remote access. Once the company participated in the software development, there is little interaction with the supplier.

4.3 Case C

The third case study is one of the world leaders' multinational company in the elevators segment. Originally a manufacturer of equipment and components, the company added services to their offerings, which currently represents its biggest profit source (92%), especially the lift maintenance services of their own products or from other manufacturers. This service consists of monthly basis preventive inspections and corrective maintenance when failures occur, being considered as smoothing service once it doesn't change the product functions. The company profits from the service provision and its outcome: the sale of new components that replace the damaged ones. However, they were having problems with the service quality due to the low performance of some maintenance technicians. To optimize its efficiency, the company acquired smart glass technology to improve the maintenance technicians' performance. The smart glasses are used as a video streaming tool via web platform, in which the technicians receive remote assistance from a specialist to guide their activities, simultaneously improving their training. Furthermore, the company also benefits from its telemetry sector responsible for the elevators sensing, which supports the fault analysis of the modern elevators, giving information to the technician about what procedures he must do in the preventive maintenance. In this PSS offering, the interviewee identified the most important capabilities: user identification, remote connectivity and control, data collection and analysis, optimization and autonomy. The web platform used was developed inside the company, whereas the smart glass technology was acquired by a supplier.

4.4 Case D

This study was conducted in a building and residential automation company. Traditionally, the company supplies only hardware products (over three million products per year) for big retainers, with little contact to the end customer. Now, the company is launching a residential automation line with smart and connected products, in which the customer can control some functions by distance, outside its residence. This offering is comprehended in a worldwide project to develop smart home products based on Bluetooth and a standard IoT protocol, in association with companies like Google, Apple, Samsung and others. The aim is to start to offer services to the end customer, which according to the director is a highly competitive capability to the company that still have no service oriented culture. Therefore, the company aims to provide smoothing services as automation projects in modules of easy installation for air conditioning, TV, curtains, lighting and stereo, all controlled by the customer through a smartphone app, which is also a channel for technical support and marketing, promoting other automations packs. This way, the customer can gradually complement its home automation by acquiring each module at a time. This is a first step to start to provide information services about customer behavior, for smart energy for example. According to the interviewee, the app was externally developed and the essential digital capabilities to enable this project were the product monitoring, predictive analysis, data collection and analysis and product optimization. Other capabilities, such as user and product identification and product autonomy were considered as important to the project.

All case studies consists in originally product firms, but with different service orientation. In Table 2 we show the strategy pursued by the companies and the digital capabilities considered as little important, important and very important to each service offering in the digital PSS.

TABLE 2 – Service, Company strategy, digital capabilities, and technologies

Service category	Service offering	Company strategy	Digital capabilities			Technologies
			Little important	Important	Very Important	
Complementary	Extension of product functions and technical support services (Adapting services) (B)	Software development with a supplier, in which the engagement of the company gave condition to provide the majority of customer support services.	Geolocation Optimization Autonomy	Predictive analysis	Product identification User identification Product monitoring Remote connectivity and control	Technical support system (Team Viewer) Sensors
	Preventive maintenance services (Smoothing services) (C)	Improvement of the service provision through the acquisition and employment of smart glass technology for remote support of maintenance technicians	Geolocation Predictive analysis	Product identification Autonomy	User identification Product monitoring Remote connectivity and control Optimization	Sensors Web platform Smart glass
	Modular residential automation projects (Smoothing services) (D)	Partnership in an international project with companies like Google, Apple and Samsung.	User identification Geolocation Remote connectivity and control	Product identification Autonomy Optimization Autonomy	Product monitoring Predictive analysis Optimization Product identification User identification	Sensors Bluetooth App Cloud platform Sensors
Substitute	Plant management services (Substituting services) (A)	Acquisition of highly technological companies and development of partnerships with startups and other technology companies.			Geolocation Product monitoring Remote connectivity and control Predictive analysis	Smart monitoring systems Diagnosis and predictions systems

5. Discussions

This research shows the variety of digital technologies applications according to different types of PSS. In sum, sensors ground the digitization to all companies as it enables the product identification and monitoring capabilities, considered as very important in all cases. As corroborated by Kowalkowski et al. (2013) and Coreynen et al. (2016), it's fundamental to monitor the parameters that ground the results of the PSS solutions. For instance, in pay-per-use contracts the monitoring capability is essential to monetize the product usage and maximize the company profits (Ardolino et al. 2017), which can also benefit from user identification, other capability considered as important in most of our case studies. In line with Ardolino et al. (2017), user identification allows the personalization and optimization of the offering, by properly charging each user for the products usage. Furthermore, remote connectivity and control was also considered very important in three cases, for its capability to remotely manage maintenance contracts and, in the substituting PSS solution, to make real-time actions in the product in cases of malfunctions that can prejudice the agreed performance (Kowalkowski et al. 2013; Rymaszewska et al. 2017). Only Company D considered the latter two capabilities with little importance, once its offering provides standardized automation modules. In other words, the customers only purchase the desired systems, with no payment dependency of how much they use each system. Although Company D aims to provide performance solutions with customer behavior information in the future, the current offering has no connectivity to the objects within customers' residence, in order to avoid their perception of privacy invasion. This perception is seen as a barrier for the use of digital technologies to improve customer relationship, according to the CEO of Company D. Another problem the company is facing towards servitization is how to manage new PSS offerings to the end customers without hampering the relationship with their direct customers, the retailers that sells products to the end customers.

The companies with complementary services considered geolocation with little importance, once this capability doesn't promote higher value to their offerings. Porter and Heppelmann (2014), and Ardolino et al. (2017) show geolocation as a capability that can increase the value offering, but doesn't consider it very important, being only essential for some types of services such as car sharing services. For the company with substituting service, Case A, this capability was considered important once the plant location can have an impact on the PSS performance, being a factor to its configuration.

In the case of technical support services, the optimization and autonomy capabilities were considered with little importance. Once the technologies that allow these capabilities are very expensive and still in its early stages in Brazil, the customers in this market doesn't properly perceived its value, according to the interviewees. However, for the other types of PSS, these capabilities are considered important or very important. In line with Ardolino et al. (2017), they support PSS focused in performance, also evidenced in the Case A with the substituting services. Optimization is usually applied with predictive analysis (Ardolino et al. 2017; Rymaszewska et al. 2017), which represents a disparity of our findings with the literature, once Company C considers the latter as little important. This can be explained once a considerable percentage of the elevators maintained by Company C are old and without updated systems that collects data, which is necessary for predictive analytics. This led the company to invest in smart glasses to improve the field services case by case, supporting each maintenance technicians' performance.

Regarding the digital capabilities, all product-oriented companies in our sample usually develop the technologies internally but with the engagement of a supplier, even though in a small representation in the offering due to the size and technological level of the manufacturing companies. Most of our interviewees mentioned that when the company has a significant understanding of the technology, the interaction with supplier decreases. This fact is corroborated with the product development literature, which shows a higher intensity of the interaction with suppliers in the first steps of product development, with a significant decrease in the product launching steps (Durmuşoğlu and Barczak 2011). Furthermore, in the case study with higher value in the service offering, Case A, the company felt the need to acquire other companies in order to maintain the capabilities internally, indicating the importance of the digital capabilities for higher-value digital PSS offerings. The acquisition of another firm has been one strategy pursued by some companies in order to develop the necessary capabilities for PSS (Xing et al. 2017). Our results may indicate an increased complexity in suppliers' engagement for higher-value digital PSS development, although further studies must be conducted to evidence this affirmation.

6. Conclusions

6.1 General findings

The adoption of digital technologies can fundamentally facilitate the provision of many services related to a product. In such context, we found specific implications regarding the relevant digital capabilities of the companies to each PSS offered. The product monitoring capability was relevant to all case studies of the research. On the other hand, the

user identification and remote connectivity and control were not considered important to the PSS with product orientation and with little interaction with the customer. The geolocation capability was important to the substituting services offering, where the location also affects how the company bill its customers, according to the product usage and its performance.

According to our findings, companies usually develop the technologies internally or buy from the supplier. However, there are factors as the lack of resources to develop specific projects or the need of adaptation to international protocols that motivate companies to make new partnerships. Therefore, this study provides empirical data which complements the servitization literature, with insights about the engagement of suppliers of digital technologies, as is commonly recommended for tradicional PSS (Ayala et al. 2019). Once few studies approach the digital technologies contribution to PSS offerings (e.g. Dalenogare et al. 2019; Frank et al. 2019), and all of the existent literature has the focus of internal solutions developed by the companies, not considering supplier-customer engagement.

6.2 Limitations and future researches

The main limitation of this study is the reduced number of case studies and interviewees. Therefore, we recommend for future researches to increase the sample in order to make comparisons between the perceived importance of the digital capabilities the companies have and the ones they need to obtain, especially with the collaboration of suppliers. This is important to understand how the essential digital capabilities could be developed with the engagement of partners, likewise the possible arrangements of collaborations, in order to successfully develop a digital PSS. Also, relevant aspects of innovation policy criteria (Frank et al. 2018) for the utilization of smart products, such as smart meters, for increasing efficiency on energy consumption should have discussion. Lastly, considering that most studies has a qualitative approach, it would also be interesting to develop quantitative studies, in order to statistically investigate the relationship between digital capabilities and the collaboration in the performances of the companies.

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