Chapter 6
State-of-the-art on Product-Service Systems and Digital Technologies

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Abstract Digitalization has undoubtedly revolutionized the way businesses think, plan and operate. This transition finds origin in the dramatic increase in demand of digital solutions, from those that target every day activities to highly-specific manufacturing processes. The last decades have been characterized for having both researchers and practitioners join efforts to innovate through solutions that are smarter, more productive and more efficient. This constant effort has accompanied the appearance of other impactful phenomena, often considered as a new industrial revolution. In a historically parallel line, companies made leaps towards exploring alternative ways to organize their business structure and relate to their customers. So is the case of Product-Service Systems (PSS), which have called for increased attention in the last years due to the extensive opportunities they offer. Recent literature raises the question of which and how sustainability advantages can be derived from PSS implementation. This study aims to understand the interactions of digital technologies and PSS through a state-of-the-art review. The authors have identified that academic literature encounters the challenge of finding digital technologies under a large cloud of different terminologies, which complicates systematization. Therefore, increased efforts will be applied to clarify the area of study and provide novel insights and results. This process will include the dissemination of enablers, constrains and possible effects of integrating digital technologies with PSS. The authors aim to contribute to the on-going discussion regarding the relationship between PSS and sustainability, specifically in applications that have high impacts, such as digital technologies.

Keywords Product-service systems · Digital technologies · Sustainability

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6.1 Introduction

The last decades have successfully demonstrated the world's potential for exploitation of human and industrial capabilities. Megatrends in manufacturing such as digitalization, automation, and connectivity are changing the way organizations and their customers perceive value. The manufacturing sector finds itself in a fierce competition for differentiators that provide a competitive advantage to achieve growth within the firm and the possibility of developing permanence within highly-innovative markets (Gebauer et al. 2011). Efforts towards the development of more efficient, flexible and automated manufacturing environments have benefitted from the revolutionary Internet-of-Things (IoT) and Internet-of-Services which enable smart manufacturing with vertically and horizontally integrated production systems (Thoben et al. 2018). Additionally, manufacturing companies have invested in the development of personalized products with value-added services, servitised value proposition which is better known as Product-Service Systems (PSS) and finds value with lifecycle concerns through cooperation and interaction of a range of stakeholders (Zheng et al. 2018).

The imminent intersection of the digital and material world could provide the infrastructure required for implementing feedback-rich systems throughout the product lifetime, facilitating information transparency and process circularity (Alcayaga et al. 2019), generating additional possibilities of achieving more sustainable processes. The convergence of these research trends has contributed to strong PSS development which although is supported by more than 20 years of research, it still requires further exploration to maximize the utilization of its capabilities.

This paper aims to understand the interactions of digital technologies and PSS by identifying enablers, challenges, and effects these two domains have on one another. A literature review is performed, justified by existing academic work which has generated a large cloud of terminologies and made systematization of this knowledge a highly complex process. Additionally, this study aims to contribute to the on-going discussion regarding the relationship between PSS and sustainability.

6.2 Theoretical Background

6.2.1 Digital Technologies

Digitalization refers to the digital representation of a product or service, which at the same time, allows easier delivery and manipulation of the mentioned assets (Bitner 2010). Consequently, digital technology has emerged as an umbrella term that aims to englobe the tools used to achieve digitalization means. According to Cambridge University's dictionary, it is directly related to applications related to the usage of connectivity and internet.

The concept of digital technologies has englobed many terms, one of them being the Internet of Things (IoT). IoT was first coined by Ashton (2009) to describe

the interconnection of physical objects through added sensors. IoT has impacted companies' processes in an unusual way, and can be considered a key element of the fourth industrial revolution (Suppatvech et al. 2019). IoT specifically comprises hardware and software to enable objects to interact and to communicate with each other, supporting the development of new services (Senzi et al. 2015).

In a recent publication, Evangelista et al. (2014) explains that the move towards a digital society does not consist in achieving that people use technology, but on the actual impact of its use and how it can transform people's lives. On one hand, dealing with digitalization and assessing its socioeconomic impact, requires more comprehensive indicators on the actual use of Information and Communications Technology (ICT) in the economy and society at larger scales. On the other hand, the intelligence capability of organizations, such as the ability to configure hardware components to sense and capture information represents a first step case companies take towards digitization (Lenka et al. 2017).

Today, both academia and industry attribute great opportunities to the emergence of "big data", a term that not just addresses the volume of information, but also refers to its variability, variety, velocity, veracity, and value (Chen and Zhang 2014). In the existing literature, several terms are used to referrer to digital technologies which vary according to context. Through this literature review, the authors aim to systemize and identify those that have a bigger impact when integrating them with a PSS perspective.

6.2.2 Product-Service Systems

In a recent definition, Annarelli et al. (2016) integrates two of the pillar contributions of PSS (Baines 2007; Mont 2001), to suggest PSS as a market proposition focused on final user's needs rather than on the production process, which allows a need-fulfilment system with radically lower impacts and enhanced environmental and social benefits.

Leaping back to 2010s, it is visible that developments such as the mobile revolution and social media, specifically led to the digital transformation of businesses giving place to anything-as-a-service business models where platforms with business networks and ecosystems were promoted. This has intensified the development of PSS and its interaction with digital technologies (Rachinger et al. 2018).

PSS is by definition not a circular business model, but it can drive organizations towards reaching targets that are intrinsic of circular business models (Antikainen et al. 2018). Sustainability concerns have created a pull towards digitalized solutions that maximize the use of tangible resources through services. This suggestion is supported by some of the original conceptualizations of PSS which included dematerialization and reinforce sustainability and competitiveness goals (Annarelli et al. 2017).

Several references suggest PSS as one of the schools of thoughts rooted in CE. However, some research studies assume positive sustainability impacts from PSS

and do not consider that they can have negative environmental impacts if they are not implemented carefully (Barquet et al. 2016). The findings from this study could be considered as potentially beneficial for the design of PSS.

6.2.3 Conceptual Integration

Several contributions in literature have explored alternative terms to PSS which induce intrinsically the digitalized conditions brought by new technologies. In this way, the value creation process needs to cope with conditions of high complexity, dynamics and ambiguity. A clear example is the proposal of Smart PSS as a concept, driven by embedded electronics and software, multisensory systems and integrated actuators (Kuhlenkötter et al. 2017). Smart PSS is a result of the digitalization of products and services as the digital connectivity between components allows autonomous interaction and enables opportunities for further development (Kuhlenkötter et al. 2017). Zheng et al. (2018) argues that its innovation possibilities are enabled by a platform-based approach and it is generated in a data-driven manner.

From one end, servitisation has been demonstrated to be a process with new distributed sources of unstructured and structured data with a high level of variety, while ensuring relative veracity and needed velocity. Servitisation can be thought of as a data-intensive process (Opresnik and Taisch 2015). From another perspective, data analytics is expected to drive the next wave of servitisation and, therefore, has the potential to become a new source of competitive advantage (Schüritz et al. 2017).

6.3 Methodology

The literature review was developed through the following three main stages suggested by Tranfield et al. (2003):

1. Planning the review
2. Conducting the review
3. Reporting and dissemination.

This methodology was followed because its argument embeds the strict development of unbiased outcomes and reliable knowledge on context-sensitive research topics.

In the first step, where the review was planned, the authors chose academic databases (Google Scholar and Scopus) to explore a representative set of keywords such as “Product-Service Systems”, “Industry 4.0”, “Digital Technology”, “digitalisation” along with their linguistic variations. Both conference and journal papers were considered and publications from 2009 onwards were selected. In the second step, the authors followed the steps represented in Fig. 6.1 to achieve reliable content

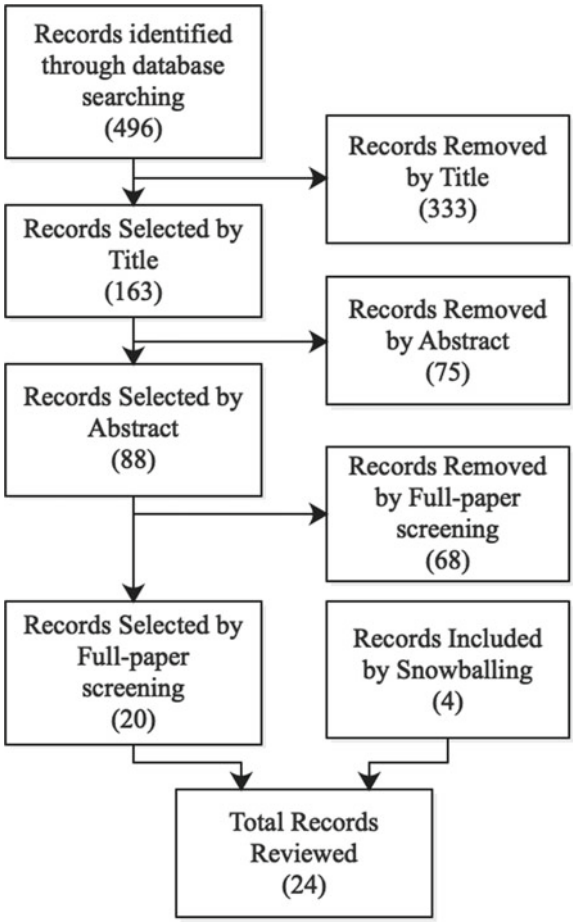

Fig. 6.1 Representation of record selection process

extraction from the records retrieved. The records which used the term "servitisation" only (i.e. not mentioning "PSS") were excluded. This decision not only helped managing the sample size, but also avoided confusion regarding the inclusion of certain study objects as services or PSS (Baines et al. 2009); e.g. controversy around the description of streaming services as part of a sharing economy (Curtis and Lehner 2019).

For the descriptive findings, the authors chose to use NVIVO as a tool for qualitative data analysis which allows to import and code textual data (Opresnik and Taisch 2015). The results from the thematic findings are summarized in Table 6.2, which was filled after an intensive analysis of records content.

Table 6.1 Word frequency in fully reviewed files

Rank	Word	Count	Rank	Word	Count
1	Product	1131	6	Value	662
2	Service	1121	7	Services	631
3	Data	981	8	Smart	597
4	PSS	755	9	Systems	569
5	Business	688	10	Digital	553

6.4 Descriptive Findings

This study focuses on the understanding of digital technologies and PSS through literary analysis. However, the authors believe that the explanation of some constitutional facts about the explored articles is useful for this study. Some of the findings include the ten most mentioned words through the analysed records, which can be seen in Table 6.1. We would like to draw our sight to the third word in the ranking of frequency: data. The constant use of this term will be further explored in thematic findings. Moreover, it shows that recent research has emphasized the need for data gathering, analysis, and usage for the integration of PSS and digital technologies.

6.5 Thematic Findings

6.5.1 Systemisation of Concepts

In literature, the on-going research on PSS finds a big challenge in the lack of systemisation of terms. According to Annarelli et al. (2016), some of the most discussed include industrial PSS, product-service combinations, product-to service, servicification (i.e. increased reliance from the manufacturing sector on services), post-mass production paradigm, functional product, total care product, integrated solutions, hybrid product, hybrid value bundles, hybrid value creation.

However, in the last years, some terms have enriched this list, such as Smart PSS, Circular PSS, and Digital PSS. Other authors refer to service additions in products as "intelligent digital systems" which allow human intervention and machine communication (Lerch and Gotsch 2015). Additionally, there are some further inconsistencies allocated to PSS and servitisation which frequently leads to semantic confusion that has negative impacts on the perception of the sharing economy (Curtis and Lehner 2019).

Likewise, the usage of diversified concepts for digitalisation and technologies can create complications for researchers and practitioners on their attempt to identify relevant literature. Some of the concepts located in (Antikainen et al. 2018) include "CPS", "big data", "Data mining", "Data analytics", "Internet of Things

(IoT)", "Mobile internet" and "Cloud computing". The diffusion of digitalization and the enhancement of digital technologies present potentialities to support the transformation towards more service-oriented strategies (Ardolino et al. 2013).

Also, the term of ICT and the growing academic discussion on how their exploitation is integral to a growing number of services (Kowalkowski et al. 2013) exemplifies through quotes such as: "the service revolution and the information revolution are two sides of the same coin" (Ardolino et al. 2016).

6.5.2 *Enablers*

This subsection describes and explores each of the seven enablers listed in Fig. 6.2 and summarized in Table 6.2. Note that big data and business analytics are strongly connected and thus discussed together.

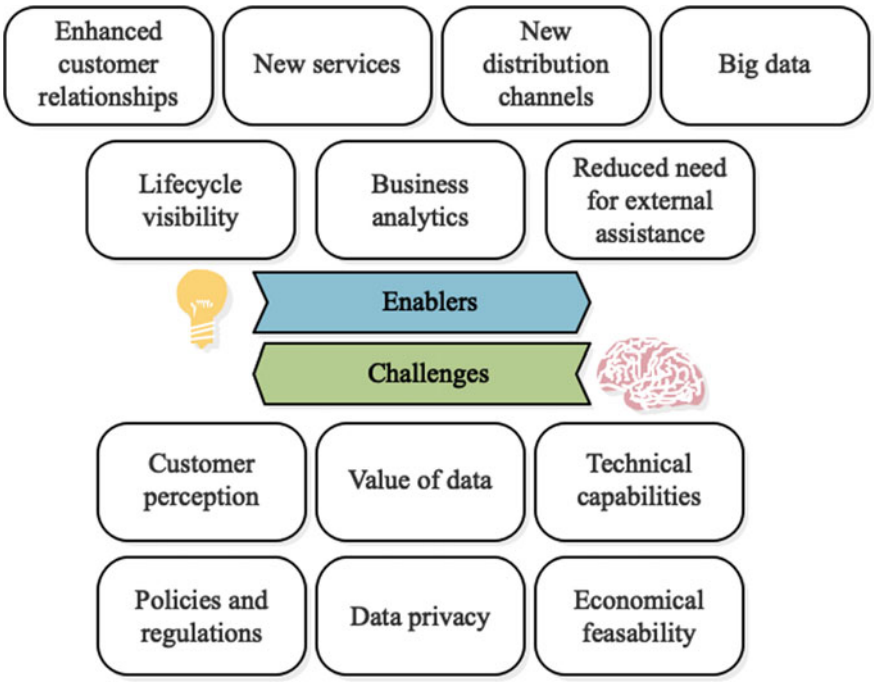

Fig. 6.2 Representation of key findings

Table 6.2 Summary of literature review findings

Reference		Thoben et al. (2018)	Zheng et al. (2018)	Alcayaga et al. (2019)	Curtis and Lehner (2019)	Lerch and Gotsch (2015)	Antikainen et al. (2018)	Ardolino et al. (2013)	Stark (2014)	Cimini et al. (2018)	Mourtzis et al. (2018)
Concept	PSS			X	X		X		X		X
	Smart		X	X						X	
	PSS	X									
	CPSS					X					
Enablers	Customer relationships	X	X	X	X	X		X	X	X	X
	New service provision	X	X	X	X	X	X	X	X	X	
	New Distribution channels	X	X					X	X	X	
	Big Data		X	X	X	X	X		X	X	X
	Increased visibility of LC		X	X			X	X	X	X	X
	Business Analytics			X			X	X	X	X	X
	Reduce need for ext. assist.										

(continued)

Table 6.2 (continued)

Reference		Thoben et al. (2018)	Zheng et al. (2018)	Alcayaga et al. (2019)	Curtis and Lehner (2019)	Lerch and Gotsch (2015)	Antikainen et al. (2018)	Ardolino et al. (2013)	Stark (2014)	Cimini et al. (2018)	Mourtzis et al. (2018)
Constraints	Value of Data	X				X	X	X	X		
	Customer perception	X		X	X			X		X	
	Tech. capabilties of customer			X		X	X		X	X	X
	Policies and regulations				X						
	Privacy of Data						X			X	
	Economical feasibility			X		X	X				

Reference		Marini and Bianchini (2016)	Süße et al. (2018)	Kans and Ingwald (2016)	Pagoropoulos et al. (2017b)	Coreynen et al. (2017)	Roy et al. (2016)	Kuhlenkötter et al. (2017)	Rymaszewska et al. (2017)	Bressanelli et al. (2018)	West et al. (2018)
Concept	PSS	X	X	X	X	X			X	X	X
	Smart							X			
	PSS										
	CPSS										
Enablers	Customer relationships		X	X		X		X	X	X	
	New service provision		X	X	X		X		X		

(continued)

Table 6.2 (continued)

Reference		Marini and Bianchini (2016)	Süße et al. (2018)	Kans and Ingwald (2016)	Pagoropoulos et al. (2017b)	Coreynen et al. (2017)	Roy et al. (2016)	Kuhlenkötter et al. (2017)	Rymaszewska et al. (2017)	Bressanelli et al. (2018)	West et al. (2018)
	New Distribution channels		X	X	X		X		X		
	Big Data	X	X	X	X	X	X	X	X	X	X
	Increased visibility of LC	X		X			X	X	X	X	
	Business Analytics	X	X	X	X		X		X	X	X
	Reduce need for ext. assist.				X				X	X	X
Constraints	Value of Data		X			X	X		X		X
	Customer perception			X		X		X	X		X
	Tech. capabilties of customer			X		X	X	X	X	X	X
	Policies and regulations				X				X		
	Privacy of Data		X	X		X	X	X	X		X
	Economical feasibility			X		X	X		X	X	

6.5.2.1 Enhanced Customer Relationships

The literature reviewed mentions repeatedly the exploitation of additional services as a potential enabler for customer loyalty and business growth (Ardolino et al. 2016). For instance, the concept of digital intelligence was found to refer to an enabler for distributed knowledge, structure, ownership and customization (Antikainen et al. 2018).

6.5.2.2 New Distribution Channels

The concepts of delivery and distribution are approached from a perspective that indicates the delivery of services and solutions through digital challenges (Ardolino et al. 2013). Additional to new distribution channels, digital technologies can enable diversified value configuration and foster partner networks (Cimini et al. 2018). These ideas are often linked to the concept of dematerialisation. Besides, the adoption of technologies such as additive manufacturing could contribute with benefits to supply chains by providing new options on the development of spare parts which increases the decentralization of production (Ardolino et al. 2013) and would mean relevant improvements in total operating and downtime costs for customers.

6.5.2.3 Big Data and Business Analytics

As mentioned in the previous subsection, literature shows repeated use of the concept of big data and data analytics, some articles even merge these two concepts into big data analytics (Wang et al. 2016; Mourtzis et al. 2018). The frequency of these concepts in the selected records can also be located in Table 6.2. The utilisation of big data is a complex decision which requires that organizations possess abilities and advanced sensing technologies (Marini and Bianchini 2016) to make use of it in an efficient, responsible and sustainable way (Süße et al. 2018). When organizations possess the abilities to make proper usage of digital technologies, they can strive to improve their maintenance activities (Kans and Ingwald 2016). For instance, it is possible to capture data from sensors located on critical components of the tangible product, transmit data gathered, (e.g. temperature or pressure), keep a record of fault codes (e.g. overheating or direct requirement of scheduled maintenance), send it directly to the manufacturer, store and analyse data. These actions enable the possibility to transform data into useful information about the product and develop responsive functions and actions such as repair, inform the customer or arrange maintenance (Ardolino et al. 2013; Lightfoot et al. 2013).

6.5.2.4 New Services

New service development was repeatedly discussed as a consequence of the usage of big data (Paschou et al. 2018). Some authors (Marini and Bianchini 2016; Ostrom et al. 2015; Lim et al. 2018) argue that big data impacts on manufacturing competitiveness not only by uncovering opportunities for new service offerings but also by capturing and analysing service-related information for effective and real-time decision making.

6.5.2.5 Lifecycle Visibility

The integration of data and information is a major enabler for the visualization of the materials cycle which can allow capturing sustainable value (Antikainen et al. 2018).

Several studies (Ardolino et al. 2016; Bressanelli et al. 2019; Pagoropoulos et al. 2017a) have studied how IoT, big data and analytics facilitate a transition towards CE. Eight main functionalities have been identified as enabled by these technologies: improving product design, attracting target customers, monitoring and tracking products, providing technical support, providing maintenance, optimizing the product usage, upgrading the product, enhancing renovation and end-of-life activities. Additionally, if organizations have data feeding their sustainability-oriented decision-making process big data and analytics can positively support lifecycle management advance towards CE (Bressanelli et al. 2019).

6.5.2.6 Reduced Need for External Assistance

Digital competence is defined as the ability to act in a digitized knowledge-based society. Additionally, this concept underlines stakeholders' capability to utilise the advantage of symmetric information as it becomes digitally spread and collectively provided (Süße et al. 2018). The understanding of this concept and its dimensions helps organizations on their path towards actively developing digitally-enabled PSS and further research is suggested in the in-depth analysis of competences within organizations (Süße et al. 2018; Paschou et al. 2018).

Also, reference is made to how data sharing can improve supplier/customer interaction (West et al. 2018). In this way (West et al. 2018) indicates that proactive data sharing can prepare the OEM to be ready to support with troubleshooting or provision of spare parts. This point is directly co-related to the reduced external assistance required by the customer and increments the responsibility of the OEM over the performance of their PSS. Augmented Reality (AR) is mentioned as a potential tool to support guidance, diagnostics, and training (Roy et al. 2016).

6.5.3 Challenges and Constraints

This subsection describes and explores each of the six challenges and constraints listed in Fig. 6.2 and summarized in Table 6.2.

6.5.3.1 Customer Perception

Regarding the identified challenges, literature expresses that on the demand side, some customers have found to have "service-for-free attitudes" where they become reluctant to pay additional fees for services added to their tangible goods (Coreynen et al. 2017; Ulaga and Loveland 2014). This situation can make the service pricing process highly difficult and poses an issue that has not been solved as of today.

6.5.3.2 Value of Data

Similarly, digital capabilities are one of the most recurrent identified challenges faced by firms who are working towards their migration to PSS offerings. In this way, we do not refer solely to the collection of data, but to the correct visualization and usage of the information that it represents (Stark 2014). The visualisation of data supports human analytical thinking and decision making. Some visualization tools, also known as visual analytics synthetize multi-dimensional knowledge from complex and dynamic data which can help support assessment, planning, and forecasting within firms (Roy et al. 2016).

6.5.3.3 Technical Capabilities

The strong requirement for companies to increase their capabilities in managing products and service variants, being agile and being ready to develop "ad-hoc solutions for customers through the so-called "co-design" process" (Alghisi and Saccani 2015) promotes value co-creation (Lenka et al. 2017). The development of suitable knowledge management approach has been expressed as essential for the successful management of all the variants (Cimini et al. 2018). Knowledge management is mentioned as one of three major areas of changes which demands that all the personnel involved remain consistent with one another to ensure long-term agreements (Cimini et al. 2018).

Kuhlenkötter et al. (2017) refers to six points of transformation through which organizations should go in order to achieve the major changes in the socio-technical system which can allow the proper development of digitalized PSS; some of these include high degrees of autonomy, strong human centration, variability and solutions along lifecycle, among others.

The capabilities of firms translate into both digital infrastructure and the availability of qualified employees who can develop and provide services with increased complexity, abstraction and the required problem-solving mindset (Lerch and Gotsch 2015). In this way, the development of abilities that allow dealing with technological devices and applications efficiently and effectively is a critical component.

Literature suggests assessment methods to ensure that companies are ready to perform in this regard (Kans and Ingwald 2016). Hence, it is commonly recognised that there is an increasing need for technical and social competencies of the employees (Cimini et al. 2018; Romero et al. 2016).

6.5.3.4 Policies and Regulations

The sharing economy is widely promoted by policy makers due to its sustainability potential, although the specific impact and possible effects are still unexplored. Some authors suggest that policy-makers who desire to institutionalise sharing as a consumption practice need to draw their sight to the possibility of negative perceptions that may exist among customers (Curtis and Lehner 2019).

In recent work, Pagoropoulos makes reference to the potential challenges that regulators and policy makers might face when integrating physical assets with service developments through digital technologies (Pagoropoulos et al. 2017b). Additionally, authors are concerned about the policy difficulties related to the use of IT (Rymaszewska et al. 2017) which is discussed further in the subsection on Data privacy.

6.5.3.5 Economic Feasibility

Another major concern is the economic feasibility of digitally-integrated PSS. It is unlikely that through vast computing power sensors with simultaneous sending and reception of data is achieved without simplicity and autonomy of end devices (Rymaszewska et al. 2015).

Besides, companies that create value offerings through PSS BMs, is that some financial risks are transferred from users to providers. More specifically, providers are often financially exposed to the risk of an early suspension of the contract by customers, when they have financed in advance the entire solution. Moreover, some cases present a time mismatch between revenue and cost streams, where providers who convert their offerings into PSS provisions find themselves having to finance in advance the capital costs of the solution and facing high-risk contracts (Bressanelli et al. 2018).

6.5.3.6 Data Privacy

Further, from a managerial perspective, the trend of digitalization i.e., the extensive use of digital technologies has enabled major business improvements such as the development of business eco-systems that are constantly reshaped by highly inter-dependent value co-creating actors (Süße et al. 2018). While this might be true, this collaborative ecosystem presents two of the major challenges, which is to first, ensure a safe data exchange (West et al. 2018) and protect the intellectual property from hackers' attacks (Cimini et al. 2018; Khan and Turowski 2016) and second, the monetising of product data through data analytics with the dilemma whether data should be available to entities that have no connection to the tangible products (Rymaszewska et al. 2015). Cybersecurity, then, becomes a technological matter that has cross importance for managing a range of elements in the transformation towards digitalization and servitisation (Kuhlenkötter et al. 2017; Cimini et al. 2018; Roy et al. 2016).

6.6 Discussion

The adoption of PSS, particularly if intended to interact with digital technologies requires a long-term perspective and in-depth understanding and involvement of users. One of the most important issues in PSS research relies on customers' requirements. The findings of this literature review have stressed on the need to further investigate the customer's perception of value associated with a PSS to further address the manufacturer's strategies (Fargnoli et al. 2018).

Some authors argue that if technological capabilities remain unchanged, the capabilities of PSS for new service development cannot be explored to their maximum potential (Rymaszewska et al. 2017; Pagoropoulos et al. 2017b). This has led recent articles to seek for interactions between digital technologies and PSS, and the role of an enabler is directed towards digitalization (Suppatvech et al. 2019; Lenka et al. 2017; Kowalkowski et al. 2013; Cimini et al. 2018; Süße et al. 2018). From this perspective, technologies such as ICT do not only enable servitisation through the provision of effective diagnostics services on the product, but it also has the potential to reduce costs, improve internal efficiency and aids increase the service business orientation of the company (Ardolino et al. 2013; Kowalkowski et al. 2013). We believe that the role and interaction of these concepts can be subjective to individual perspective and vary according to the unit of study.

An interesting point is only one of the records explored referred to organisational culture as an enabler of the servitisation process and explained the particular role of leadership, vision, and marketing as part of the effectiveness directional of servitisation strategies (Ardolino et al. 2013). A big majority of authors referred to

this element of analysis from a negative perspective considering it a challenge. This study finds a limitation on the usage of terms which have absorbed a broad range of concepts and on the consideration of case studies from a wide set of industries. To overcome these concerns, the authors suggest focalizing companies that share as many characteristics as possible.

6.7 Conclusions

In this paper, the authors aimed to characterise the interactions between PSS and digital technologies, and to position further research which can contribute to the implementation of more successful and sustainable PSS.

Through the findings, a list of enablers and constraints were identified to understand the current scenario. This way a set of seven enablers and six constraints are presented and explained thoroughly. Through their analysis authors conclude that implementation and operation of efficient PSS which comply with sustainability concerns depend highly on the appropriate and in-depth consideration of other organizations and stakeholders involved in the process. Consequently, some of the most discussed results include the relevance of data monitoring, collection, and analysis and it is emphasized as an enabler for better-informed decisions which can support more sustainable and efficient operations through a PSS lifecycle.

The organizational capabilities in both cultural and technological aspects have shown potential for a strong impact in PSS transition. Also, the possibility of new distribution channels is highlighted in the literature as an unexplored area where the usage of manufacturing technologies could represent revolutionary changes in the costs of logistics and downtimes.

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