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Product-service systems: a literature review on assisting development

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Abstract**—** *The circular economy is gaining more space amongst academia and industry as a path toward sustainable development. The Product Service System (PSS) is pointed as a business model with a high potential of achieving circular economy, specially through efficient consumption and production. Even though literature on PSS is somewhat extensive and has been growing over the years, PSS is still troublesome to adopt, due to a lack of organization of the existing knowledge. This research seeks to gather and organize PSS development approaches (tools, methods and processes) presented in the literature, according to the PSS lifecycle. A bibliographical analysis was conducted, gathering researches in which PSS development approaches were mentioned. The approaches were later categorized, and their applications were analyzed. MePSS, PSS Board, Service Blueprint, and Business Canvas Model are some of the main approaches studied. Analysis showed research gaps concerning practical knowledge on the PSS field and approaches that comprehend the whole PSS lifecycle, completing the circularity of the product-service offer. Future research could aim at fulfilling those gaps, applying conceptual elements of Product-Service Systems and supporting the transaction toward a more circular economy.*

Keywords**— Circular Economy, Product-Service System, PSS Development, PSS Lifecycle.**

I. INTRODUCTION

In the modern industrial context, where industries are being pushed into reconsidering their ways of production because of tough competition, environmental policies, risks, and pressure from consumers [1], [2], the Circular Economy steps up as a path toward sustainable development [3]. Circular Economy is considered a regenerative system that aims at reducing resource consumption and energy and waste emission by closing the loop on production and distribution [3].

Authors have stated Circular Economy's benefits and links with the environment, the economy [3] and society [4]. Even though shifting from a linear business model to a circular one may be challenging [5], it is necessary for achieving Sustainable Development Goals [6]. One way of enabling circular solutions and reaching environmental, economic and social benefits is through servitization [7], [8], i.e., providing services to complement product offers [9].

A model which seeks to apply this shift, focused on sustainability [10], is the Product-Service System (PSS) defined as a set of products and services capable of satisfying customers' demands when combined [11]. Despite its benefits for company's competitiveness and the spheres of sustainability [12]–[14], PSS is still limitedly adopted [1].

A possible reason for this is that companies require "suitable models, methods and tools" that allow them to achieve customers' requirements [9] and support their transition to long-term offers [2]. However, although literature addresses these tools, they lack practical guidelines and biases for industry practitioners [15], [16].

Considering those issues, this research aims at congregating the main PSS approaches existing in literature, presenting industry stakeholders with a compilate of tools, methodologies and processes that can be used to support the development of a PSS offer considering its lifecycle. Some of the approaches are deeper analyzed, and some conclusion are taken regarding PSS contribution to Circular Economy.

The paper is organized as follows: Section 2 presents a background on Product Service Systems and its lifecycle

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and Section 3 presents the research methodology. The main PSS approaches are exposed in Section 4 and these results are discussed in Section 5. Finally, Section 6 presents some conclusions and suggestions for future work.

II. LITERATURE BACKGROUND

The concept of a joint offer of products and services seeking to add value to customers' needs with less impact on the environment derived from the proposal to shift the focus from selling products to selling their functions [17]. Consequently, highly materialized ways of production and consumption can be replaced by a dematerialized culture, providing satisfaction through services [18].

On this matter, PSS can be defined as a business model which seeks value in the usage instead of the ownership and provides a different approach to fulfill consumers' needs with the combination of products and services [14], [15].

Mont [18] defined four elements that must be considered when developing an offer, in order to ease the transition and provide quality to customers: the products, the services, the infrastructure and the actors network.

The product sphere refers to the need to comprehend the way the product is used so services can be combined, e.g. choosing between renting or sharing. The service sphere shows the change in marketing strategies to sell usage rather than volume of products. The infrastructure sphere contains the systems required to support the PSS offer, e.g. roads for car sharing. The actors network consists of the alliances that should be forged between stakeholders to add value to the PSS [19].

When developing a Product-Service System, there are requirements to be fulfilled and sub-systems to be established [9], [20]. These requirements, however, are not the same for the creation and offer of services and the traditional product-based manufacturing system [9]; PSS sub-systems are more complex than products or services ones alone, as they incorporate tangible and intangible components on the same offer [20].

Many PSS design approaches develop the system through sequential steps (e.g. [21]–[23]). In most cases, this step-by-step process is the illustration of a product-service system lifecycle. Authors ([24]–[26]) have stated the importance of systematically develop PSS through its lifecycle, as value is created in the system throughout the cycle [24], [26].

Wiesner *et al.* express that there isn't only one defined cycle for PSS, but all the existing ones surround three basic stages: Beginning of Life (product conception), Middle of Life (product use) and Ending of Life (product disposal) [27]. Many authors ([1], [9], [22], [27]–[30]) presented PSS lifecycles based on these concepts.

Beuren *et al.* [30] proposed a PSS cycle with 5 stages, which were chosen to guide this research. The first stage, PSS Requirements Definition, comprises organizational pre-requisites for the PSS [22] aiming at fulfilling customer needs [31]. PSS Development shows how the system is going to be developed, integrating product, service, infrastructure and actors network [30], [31]. The Implementation phase comprehends PSS installation, tests, delivery and use [30]. On the Monitoring stage, the system's conditions are monitored in order to decide between improving the offer or ending its life [30], [31]. If ending of life is the case, responsible ones can choose between replacement, recycling or product take back [32] on the Destination After Use stage of the cycle.

III. RESEARCH METHODS

Many authors [19], [25], [26], [28], [33]–[38] have listed different PSS approaches with different emphases. However, a clear link presenting the approaches and the PSS lifecycle with a practical focus for the industrial context hasn't yet been explored [2], [9], [15].

Regarding this topic, this research was conducted in three stages, as shown in Fig. 1.

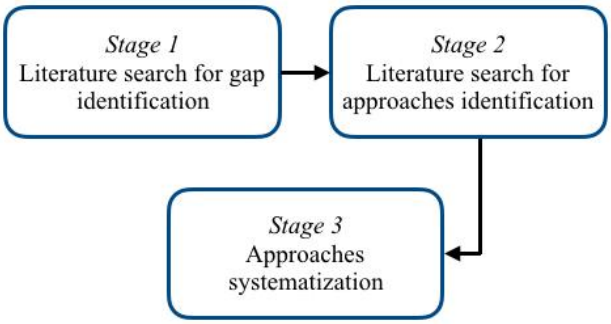

Fig. 1: Stages of the research

The first stage consisted in gathering research gaps presented by researchers on the PSS field. A bibliographical analysis was conducted, gathering papers published between 1999 and 2017. The search parameters are presented in Table 1.

From the 210 files encountered in Stage 1, the three authors with most publications were selected, and their recent papers (2015-2018) were fully read. The research gaps they presented were organized in tables, presented in Section 4.1.

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Some of the gaps the authors pointed showed a lack of practical approaches to develop a PSS. Aiming at fulfilling those gaps, Stage 2 of the research focused on PSS development supporting methodologies. A new search was conducted in Scopus and Web of Science academic databases, searching for the PSS approaches on articles published between 2008 and 2017, as shown in Table 2.

In total, 196 papers were encountered. The title, abstract and keywords of the papers were skimmed, looking for those papers which would bring us the tools and methodologies we were looking for. This selection resulted in 87 papers, that were fully read.

Table.1: Literature search in Stage 1

Main keywords	**Databases**		**Number of papers**	**Combined keywords**	**Number of papers**
(phase 1)	Scopus	Science Direct		*(phase 2)*	
Product-service system	553	183	678	Sustainability; remanufacturing; service design; service economy; dematerialization; system solution; functional economy	188
Servitization	249	127	310		34
Productization	47	2	48		1
Databases total:	849	312	1036		223
				Non-duplicated files (phase 3):	**210**

In Stage 3 of the research, the PSS approaches were classified according to the PSS lifecycle stage they attended. Also, the approaches were cataloged into the four elements of a Product Service System according to Mont [18], i.e. products, services, actors network and infrastructure, and into the type of approach they are presented as: method, tool or process.

Table.2: Literature search in Stage 2

Main keywords	**Complementary keywords**	**Number of papers on databases**	
(phase 1)		Scopus	Web of Science
Product-service system + methodology	Development; developing; implementation; implementing; modeling; disposal; post use; after use; post processing	108	178
Product-service system + tool		100	145
	Database total:	208	323
	Non-duplicated files *(phase 2):*	196	
	Selected for full read (phase 3):	**87**	

The results found in the gap analysis and the search for PSS development approaches are listed in Section 4.

IV. RESULTS

This section explores the results obtained on the three phases of literature search and data analysis. Section 4.1 presents the results from Stage 1 – a content analysis of PSS main authors, and Section 4.2 presents the results from Stages 2 and 3, listing the main approaches for PSS development, according to its lifecycle stages.

4.1. Results for Stage 1: research gaps analysis

Based on the 210 papers gathered on the bibliographical analysis and the defined criteria, three authors were selected: Carlo Vezzoli, Fabrizio Ceschin and Tomohiko Sakao. A table was assembled to organize the information presented in their research, emphasizing the research gaps they presented (see Table 3).

Sakao's papers focus mostly on the value PSS adds to the provider, and, in this scope, he shows the lack of practical knowledge on the field and that providers need that knowledge to develop profitable PSS offers. Vezzoli

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and Ceschin point out the need to organize that knowledge. A similar conclusion was made by [35]. As presented in this paper's methodology, this gap guided the search to look for approaches to assist on PSS development, which are explored in Section 4.2

It should be noticed that we could not get access to several papers among the research gathered in the bibliographical analysis.

Table.3: Research gaps presented by the main authors

Reference	Research gaps
[39]	Practical methods to efficiently create modules for PSSs have yet to be developed for industry.
[40]	There is a much-needed faster development of knowledge in the sustainability discipline.
[41]	The main challenges are to organize the available knowledge in an accessible way (including training and educational programs) and to develop an open case base including Sustainable PSS concepts.
[42]	It could also be argued that interdisciplinary research lacks visualization: that is, it is difficult to determine or explicitly see how an insight has been used. Further research could communicate this in a clearer manner.
[43]	Future research may focus on developing a more comprehensive conflict resolving approach incorporating TRIZ tools more often.
[44]	Industry practitioners are still struggling with the adoption of PSS.
[45]	To continue to meet customer requirements more promptly, it is effective to take forecast of customer requirements into account in the framework.

4.2. Results for Stages 2 and 3: Main approaches for PSS

We realize there are differences among three types of approaches (method, tool and process) within the PSS field, even if a search on Google or on dictionaries tells us they are synonyms. A way of justifying this is taking a look on works like [2], which uses three words to refer to PSS development approaches: tools, techniques and methods; or even considering why one of the main PSS development approaches, Methodology for Product Service System Development (MePSS) is defined as a methodology that provided a toolkit [15], [46]. The same choice of words was used on [17] and [21]. A more extensive list of examples includes [9], [15], [34], [47].

In order to maintain the approaches developers' directions, we classified the approaches into methods, tools and processes according to what the papers we read had categorized them. The reason why some of the them are tagged as "undefined" is because the papers didn't put them in any category.

We chose to rank the approaches by two criteria: the most cited approaches on our 87-paper library, and the ones that fulfilled most of Mont's [18] four elements of a PSS.

It's important to state that the authors cited on the reference columns on tables 4-8 refer to those who mentioned the employment of the referred approach on the referred lifecycle stage and are not necessarily the approaches' developers.

In order to not present an exhaustive list of approaches, the lists below (tables 4-8) do not represent the entire scope of approaches encountered. The entire scope comprehends: 68 approaches for PSS requirements definition; 89 approaches for PSS development; 15 approaches for PSS implementation; 25 approaches for PSS monitoring; and 4 approaches for PSS destination after use.

The abbreviations A, P, S, I exposed on tables 4-8 stand for actors' network, product, service and infrastructure, respectively.

The first stage of the PSS cycle, PSS Requirements Definition, aims at defining pre-requisites for the system, in order to fulfill consumers' needs and achieve their satisfaction. Table 4 shows the PSS main approaches on the Requirements Definition phase.

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Table 4. Main approaches on PSS Requirements Definition stage

Approach	Category	Nº citations	References	A	P	S	I
Service Engineering	Undefined	6	[48]		X	X	
PSS lifecycle model	Undefined	1	[49]	X	X	X	X
Model to integrate products and services on PSS development, adapted from IDEF0	Undefined	1	[50]	X	X	X	X
QFD (Quality Function Deployment)	Method	13	[19], [25], [28], [36], [51], [52]	X	X	X	
MePSS	Method	12	[34], [48], [53]				
Service CAD	Method	8	[9], [54]	X		X	
Business Canvas Model (BCM).	Method	4	[28], [54], [55]	X	X	X	X
System Dynamics	Method	4	[56]	X	X	X	X
Practical design framework	Method	2	[1]	X	X	X	X
Service Explorer	Tool	11	[9], [33], [35], [48], [49]		X	X	
Service Blueprinting	Tool	10	[28], [29], [34], [37], [49]			X	
PSS Board	Tool	4	[16]	X	X	X	X
FEPSS	Process	1	[28]	X	X	X	X
Developing method on service-oriented PSS	Process	1	[26]	X	X	X	X

On the second stage of the cycle, PSS development, the requirements will be aligned with the four elements of a PSS, i.e., product, service, actors' network and infrastructure; the conceptual ideas are put in motion. Table 5 presents the main PSS approaches on the development stage.

Table 5. Main approaches on PSS Development stage

Approach	Category	Nº citations	References	A	P	S	I
A model to integrate products and services in a PSS, adapted from IDEF0	Undefined	1	[50]	X	X	X	X
MePSS	Method	12	[19], [21], [34], [53], [54]				
QFD (Quality Function Deployment)	Method	12	[26]	X	X	X	
Service CAD	Method	8	[1], [25], [28]	X		X	
System Dynamics	Method	4	[57]	X	X	X	X
Practical design framework	Method	2	[1]	X	X	X	X
PSS for machine-tools	Method	1	[54]	X	X	X	X
PSS evaluation method through a 94 criteria framework	Method	1	[26]	X	X	X	X
5 stages to characterize PSS	Method	1	[58]	X	X	X	X
Service Explorer	Tool	11	[1], [9], [33], [59]		X	X	

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Service Blueprinting	Tool	10	[19], [34], [36]			X	
Product-Service Blueprint	Tool	4	[26], [29], [33], [34]	X	X	X	X
PSS Board	Tool	4	[26]	X	X	X	X
FEPSS	Process	1	[28]	X	X	X	X

On the third stage of the cycle, PSS implementation, the offer is delivered and used by the consumer; the phase comprehends product installation and service implementation. Table 6 presents the main approaches for PSS Implementation.

Table 6. Main approaches on PSS Implementation stage

Approach	Category	Nº citations	References	A	P	S	I
PSS lifecycle model	Undefined	1	[49]	X	X	X	X
QFD (Quality Function Deployment)	Method	12	[26]	X	X	X	
Business Canvas Model (BCM)	Method	4	[60]	X	X	X	X
Practical design framework	Method	2	[1]	X	X	X	X
Product-Service Blueprint	Tool	4	[34]	X	X	X	X
PSS Board	Tool	4	[29]	X	X	X	X

The fourth stage of the cycle, PSS monitoring, is the one where the system's conditions will be evaluated in order to decide for its improvement or disposal. Table 7 presents the main approaches on PSS Monitoring stage.

Table 7. Main approaches on PSS Monitoring stage

Approach	Category	Nº citations	References	A	P	S	I
Life Cycle Assessment (LCA)	Undefined	3	[61]		X		
PSS lifecycle model	Undefined	1	[49]	X	X	X	X
FMEA	Method	5	[36]			X	
System Dynamics	Method	4	[62], [63]	X	X	X	X
Practical design framework	Method	2	[1], [28]	X	X	X	X
Product-Service Blueprint	Tool	4	[34]	X	X	X	X
PSS Board	Tool	4	[29]	X	X	X	X
Discrete Event Simulation (DES)	Tool	4	[49]			X	

After a PSS offer is evaluated, if decided that it doesn't satisfy consumers' needs anymore, the offer is disposed: replaced, recycled or taken-back. Table 8 presents the main approaches for PSS Destination After Use, the last stage of the referred PSS cycle.

Table 8. Main approaches on PSS Destination After Use stage

Approach	Category	Nº citations	Reference	A	P	S	I
Practical Design Framework	Method	2	[1]	X	X	X	X
Methodology for PSS development	Method	2	[28]	X			
PSS lifecycle model	Undefined	1	[49]	X	X	X	X

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Some of the approaches presented on tables 4-8 are able to be employed into more than one phase of the PSS lifecycle. They were also classified as principal approaches on this research – either for being cited by many different papers or for fulfilling most of PSS elements proposed by Mont [18].

The Methodology for Product Service System Development (MePSS) is pointed as one of the main approaches to PSS design [25], [38], [41]. It has a great focus on sustainability and strategic analysis. The approach presents the system's development in a practical way, through customer requirements with support from various tools [48], [53].

Service Blueprint is a service visualization tool in terms of actors behavior and relationships [29], [34]. It is widely used for service design [19], [34], and it is composed of a vertical axis, representing the processes, and a horizontal one, representing actors' actions [49]. Even if the tool is also widely applied into the design of PSSs [34] it is not ideal for the referred task, as it focuses on services only, and does not consider other elements important for PSS design [19].

For that matter, Geum and Park [34] developed a tool called Product-Service Blueprint, extending Service Blueprint to PSS in order to satisfy its characteristics. The authors added different symbols to the framework and developed it through Mont's [18] four elements of a PSS. The result was a tool for concept development, activities identification, and building of relationships by linking stakeholders to products, services and supporting areas.

Lim *et al.* [29] developed the PSS Board, a visualization tool for PSS. The framework is a 45 cell-matrix, in which Mont's [18] four elements of a PSS and customer activities are presented in rows, and PSS general processes in columns. The authors state that the tool measures strengths and weaknesses of a PSS, with the main goal of presenting PSS scenarios and the way PSS components relate to each other [29].

The Business Model Canvas (BMC) is a widely known method to design business models [55]. For PSS, the method allows the choice of the best PSS type (i.e. product, use or result oriented PSS), and its nine blocks (value proposition, customer segments, distribution channels, customer relationship, revenue streams, key resources, key activities, key partners and cost structure) work as direction vectors for the design and implementation of a PSS, as the system's characteristics are built from these blocks [60].

The results presented in this section will be explored and discussed in Section 5.

V. DISCUSSION

It can be noticed that most of the PSS approaches gathered are congregated on the first stages of the PSS lifecycle. That can be seen as we move down on the paper and forward on the cycle stages, since the number of approaches in Tables 4-8 gets sequentially smaller. Also, the total number of approaches gathered among this search moves down from 68 approaches on PSS Requirements Definition to 4 approaches on PSS Destination After Use. This smaller amount of approaches on the former stages of the cycle was also pointed out by [2].

This could be explained because every system needs requirements to be developed [64]; even if the developers don't plan and write down the requirements, they exist. But not every system is planned with an expiration date, planned to be disposed, even Product Service Systems, as the cultural environment of product-service offers is still in adjustment [65]. In addition to that, it has been stated before [66] that not every PSS is oriented to Circular Economy, i.e. not every PSS is designed with a closed loop.

Furthermore, if we consider the development of a product-service offer through conceptual elements, as proposed by [30], it can also be noted that the number of conceptual elements regarding the PSS Requirements Definition phase is more significant than the number of conceptual elements for PSS Destination After Use phase (see [30]). With less conceptual elements to achieve and complete, less approaches could be necessary.

Moreover, authors [67] express that the PSS conceptual design phase – which stands for PSS Requirements Definition *plus* PSS Development – is crucial to ease the planning and development of other stages of the PSS lifecycle – another fact to justify the greater number of approaches on the early stages of the cycle.

From the approaches studied, many authors and proposed methods suggest the use of existing tools within the approaches. TRIZ tools are cited for PSS requirements generation and PSS development (e.g. [37], [48]), moving forward into filling the gap presented by [43] (see Table 3). But even with these initiatives, there aren't many approaches regarding TRIZ tools and the resolution of conflicts, so they could be further explored.

Generally, methods are broader, and sometimes comprehend step-by-step processes, in which the steps can be fulfilled with the employment of a tool – which are usually more practical and specific approaches. This indicates the possibility of collaboration between approaches, enabling and encouraging the accomplishment of a finer result.

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Another interesting fact to point out is that the monitoring phase of the PSS lifecycle is mostly composed by simulation methods. These methods can be used to comprehend the link between system's variables and predict its behavior, playing a role of 'handler of system's complexity' on PSS [68]. As Product Service Systems are comprised by four elements and must be developed aligning them, this development process is a complex one [69]. Simulation methods can be of help on this matter, predicting system's conditions or the best way of combining variables.

Some of the approaches encountered can be employed into more than one stage of the PSS lifecycle, as pointed in Section 4.2. In fact, they are ranked as principal in those stages, e.g. PSS Board [29] and Practical Design Framework [1] for PSS Requirements Definition, Development, Implementation and Monitoring. Even though there are some approaches, this number is still not very significant, and PSS developers don't have a lot of options on the table to choose one to work with. Also, even if these approaches cover many of the PSS lifecycle stages, an even smaller amount of them covers the PSS Destination After Use stage.

It's important to assert the relevance of a PSS development supporting approach that addresses the whole PSS lifecycle. This enables stakeholders to guarantee that their system will be designed and put in motion with a closed loop on production, consumption, distribution and final destination, validating the statement from some authors (e.g. [10], [70]) that a PSS is a way of contributing to a Circular Economy.

VI. CONCLUSIONS

This research had the purpose of congregating the main PSS approaches existing in literature, presenting industry stakeholders with a compilate of tools, methodologies and processes that can be used to support the development of a PSS offer considering its lifecycle.

In order to do this, a bibliographical analysis was conducted to gather PSS approaches presented in the literature, and the approaches encountered were classified into the PSS lifecycle stage they attended, into Mont's [18] four elements of PSS, and into the type of approach they were presented as: tool, method or process.

It was noted that there was a more significant number of approaches in the first stages of the PSS cycle than in the last stages. Some reasons to explain this condition were presented in Section 5. It was also observed that some approaches could be employed in more than one stage of the PSS lifecycle and that some of them were designed to be employed along with others, allowing the accomplishment of a more valuable result.

One suggestion for future work would be to link these approaches encountered for each stage of the PSS cycle with the conceptual elements for the stages, as they work as a checklist for the development of a new Product-Service System. This proposal could be of a conceptual model to PSS development, encompassing the whole PSS lifecycle.

Also, more research could be conducted in order to develop different approaches (e.g. tools) for the last stages of the PSS lifecycle, specially the former stage. Approaches from other fields can't be borrowed for the product-service disposal, as they can for PSS monitoring or implementation, for example.

This research is relevant as it works as a step forward into filling the gaps presented by [2], [9], [35]. Product-Service Systems are viable options for contributing to Circular Economy and to satisfying customer needs with sustainable and profitable options, if rightfully developed.

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