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PRODUCT SERVICE SYSTEM: A CONCEPTUAL FRAMEWORK FROM A SYSTEMATIC REVIEW

Alessandro Annarelli, Cinzia Battistella, Fabio Nonino

Abstract

This paper sets out to contribute to a critical theory debate through the presentation and use of a framework for the categorisation of literature linked to Product Service System (PSS).

Moving from the analysis of literature we provide a conceptual structure depicting the current situation of literature dealing with the analysis of economic impact and environmental/social impact of Product Service System. Moreover, we provide a methodological structure, concerning methodologies and research purpose behind papers.

Despite the lack of a unique and well-accepted definition, authors seem to agree in recognizing the PSS as a business model, although this necessitates a deeper theoretical insight.

Literature mainly agrees about PSS benefits, barriers, and partly also on drivers, but from the descriptive and thematic analysis what emerged is a lack of clarity about PSS and its main fields: it started as a topic closely connected with sustainability, but subsequently different fields have developed other terminologies and focuses of research, developing their own theoretical base and frameworks. Therefore, we have found a lack of interconnection among fields and subject areas.

A critical aspect in current literature is about the analysis/evaluation of Product Service System performance: economic and environmental analyses should be updated with new methodologies and new perspectives (i.e. privileging an ex post perspective rather than an ex ante one). Furthermore, these analyses should be integrated in a unique tool, which would be essential in providing a complete perspective on the PSS phenomenon and its effects.

Finally, we propose and discuss main future research directions, connected to the main current research streams: sustainability, Product Service System business models and collaborative consumption.

Keywords

Product Service System, Servitization, Post Mass Production Paradigm, Industrial Product Service System, Functional Sale, Systematic Review

1. Introduction

A business strategy based on Product Service System (PSS) establishes a value proposition focused on final users' needs rather than on the product (Baines *et al.*, 2007), allowing for an easier design of

a need-fulfilment system with radically lower impacts, in terms of environmental and social benefits (Mont, 2002). In their work in 2003, Manzini and Vezzoli provided examples of organizations employing PSS offerings: this is the case of AMG offering a "solar heat service": "The consumer pays for receiving a service, comprehensive of final result, from installation to the thermal-energy meters and the transportation of methane to the boilers. It also granted the maintenance of the equipment." (Manzini and Vezzoli, 2003). Thanks to this, "firms will have an incentive to prolong the service life of products, […] to make them as cost- and material-efficient as possible, and to re-use parts as far as possible after the end of the product's life" (Tukker, 2015). Furthermore, product design and manufacturing can no longer be the only source of competitive advantage and differentiation: product-service integrated solutions bring innovation potential, adding value to the total offering (Roy and Cheruvu, 2009). This could be the simple case of extra services added to the product offering, with the aim of prolonging product life cycle and utility through time (for a more sustainable performance), while providing to customers a more satisfactory experience, worthy of extra revenue.

PSS is a research topic closely linked to business model innovation and sustainability: this is a sub-field of research attracting increasingly more interest from different streams, as evidenced by Boons and Lüdeke-Freund (2013).

Understanding how the transformation of business models happens, how "the journey to sustainability" happens, is a key topic attracting the attention of a rising number of scholars, though it is still at a conceptual level, not addressing "the question of the processes through which these new business models are developed by businesses and their managers." (Roome and Louche, 2015)

In business model literature, in recent years, some interesting topics have emerged, proposing feasible ways to business innovation linked to sustainability concerns, like sharing economy (as recently reviewed by Cheng, 2016), and circular economy (Witjes and Lozano, 2016). As stated above, these topics are closely linked to PSS, and can be seen as a sub-field of PSS/servitization stream of research. While research about PSS and servitization has been well established for more than 20 years, there is still growing attention and the need to explore some of its aspects.

Traditional manufacturing firms recognise that services in combination with products could provide higher profits (Becker *et al.*, 2008, Lockett *et al.*, 2011); moreover, with a strong interest in sustainability (especially for social and environmental aspects), new phenomena like collaborative consumption (e.g. car-sharing, bike-sharing) are becoming important for firms. PSS is attracting more and more attention as the boundaries between product and service offerings becomes blurred: that is why it appears to be an optimal "strategic alternative for sustainable development of firms" (Park and Yoon, 2015). As also Morelli (2006) pointed out, "the epochal shift from product-centred mass consumption to individual behaviours and highly personalized needs is now driving firms to rethink

their industrial offerings." For example, the HiCS (Highly Customized Solutions) research project developed a solution called *Punto X*: "a system of products, services and expertise, able to offer food solutions that are personalised to meet the needs of specific contexts-of-use. The personalisation is obtained thanks to the flexibility in the meal composition, the organisation of distribution and delivery systems, and through service/consumer interfaces." (Krucken and Meroni, 2006).

PSS allows modern organizations to meet these new *evolved needs*, by also maintaining a clear focus on sustainability needs, which are always more pressing in organizations' core businesses (Cook *et al.*, 2006). In this way it is possible to operate a shift in the offerings, securing competitiveness and sustainability at the same time (Azarenko *et al.*, 2009, Beuren *et al.*, 2013).

From a literature point of view, themes such servitization and dematerialization, especially in association with the theme of sustainability, continually attract interest from different research fields, such as operations research, marketing, business, management and accounting, engineering design. Although these topics emerged during the '90s, they continued attracting interest and the number of publications is in constant growth, probably because of the convergence of particular causes over the years (like ICT spread, and their wide employment in manufacturing).

Since its origins, PSS attracted the interest of design researchers, because of its nature as a socio-technical system: the term first appeared in 1960 and was coined by Emery and Trist "to describe systems that involve a complex interaction between humans, machines and the environmental aspects of the work system. The corollary of this definition is that all of these factors — people, machines and context — need to be considered when developing such systems using Socio Technical Systems Design methods." (Baxter and Sommerville, 2011)

The main objective of our literature-based research is to show possible conceptual and practical interrelations and to highlight the past and emerging research stemming from different fields and subject areas. After a description of the methodology adopted (a systematic review), we reveal results subdivided in descriptive findings and thematic findings, we propose a conceptual structure and a methodological one and we conclude by discussing academic implications and future research directions.

2. Theoretical background

A Product Service System (PSS) is as a market proposition that extends the traditional functionality of a product by incorporating additional services (Baines *et al*., 2007).

Literature on PSSs began to emerge after the publication of the work by Goedkoop *et al.* in 1999, with seminal works like those by Mont (2002), Manzini *et al.* (2001) and Tukker (2004), and the significant literature review by Baines *et al.* in 2007. The number of publications about PSSs, as well

as scholarly interest, has continued growing until the present, with considerable academic production, as evidenced also by the works of Tukker (2015), Beuren *et al.* (2013), and Reim *et al.* (2015).

Before the appearance of the above mentioned research explicitly dealing with PSS, literature was already dealing with a topic strictly linked with PSS: *servitization*. In fact, both these topics concern the concept of "adding value to their core corporate offerings through services" (Vandermerwe and Rada, 1988). The difference lies in the meaning behind these two terms and in the context in which they are used: although describing the same concept (i.e. "a marketable set of products and services", Goedkoop *et al.*, 1999), Product Service System is usually used when there is a major interest in the sustainability potentials of the offerings, while the term servitization is mostly used in a purely economic context.

Moreover, during the years several terms have been created to indicate the same or similar notions (Lisfet, 2000): *industrial product service system* (Meier *et al.*, 2010), *product service combinations, product-to-service, servicification* (European Commission, 2014); *post mass production paradigm*: (Tomiyama, 1997)*; Functional sale* (Sundin and Bras, 2005) and *functional product* (Lindström *et al.*, 2012); *total care product* (Alonso-Rasgado *et al.*, 2004) and *integrated solutions* (Davies, 2004); *hybrid product, hybrid value bundles* and *hybrid value creation*.

As evidenced by Boehm and Thomas (2013), PSS attracts interest from many disciplines. It is an interdisciplinary field, because it presents interesting and challenging characteristics for many researchers from different research areas. Business Management mostly investigates the bundling of products and services from a marketing perspective, while in the Engineering & Design field the focus is on designing, developing and delivering the PSS to the final user, together with a developing interest from the ICT and Information Systems disciplines, because of the increasingly close relationship between PSS and technology.

3. Research methodology

3.1.Research aim

The purpose of this work is to understand the origins, the current state-of-the-art and the possible future research directions on PSS, in order to give an overview of the current knowledge, discover gaps in existing literature and identify interesting topics for further research. Our analysis will then be focused on the investigation of a gap emerging from the theoretical background: the analysis of economic and environmental/social impact of PSS. In fact, at the current stage of development of this research domain, there is still a need to clarify and assess the impact of PSS on all three dimensions of the so-called Triple Bottom Line (Lee *et al*., 2012a): economic, environmental, and social.

This is an aspect that needs to be clarified and developed in detail, in order to provide scholars and (especially) practitioners with a series of tools and methodologies capable of clearly expressing and

quantifying PSS potentials. Authors dealing with this topic started early to ask themselves if PSS could really provide the benefits expected, in economic and environmental terms (like Tukker and Tischner, 2006), but nowadays interrogatives of this kind are lacking and our aim is to raise the interest in these crucial aspects. Therefore, we address the following research questions:

RQ1 *What are the bases of the research on PSS?*

RQ2 *What are the outcomes of the research on PSS, intended as current and future research streams?*

RQ3 *What are the benefits and barriers of PSS?*

RQ4 *How can we critically define a content framework for the categorisation of literature linked to PSS?*

3.2.Systematic review

The methodology we adopted is a systematic review (Pittaway *et al.*, 2004; Collins and Fauser, 2005; Macpherson and Holt, 2007). We chose it because it differs from traditional reviews by using a scientific and transparent process, aiming at minimizing biases thanks to an exhaustive search of works published in literature. We followed three main steps, as suggested by Tranfield *et al.* (2003):

1. *Planning the review*. We decided to focus on PSS and its main research fields (and sub-fields), which is the main purpose of this work: that is why we decided to look for only those articles explicitly using the term "Product Service System", or indicating it as synonymous, together with the other terms reported above.
2. *Conducting the review*. About the topic and its boundaries, we searched for "product-service system" or "product service system" (in Title, Abstract and Keywords). The second step regards definition of sources: we decided to use Scopus online database for our research, because compared to other sources, as also evidenced by Tukker (2015), Scopus is a tool for electronic literature search, particularly good for works published after 1995, and it has a wide range of subjects and journals. The next step was the identification of selection/exclusion criteria, and we wanted to focus only on articles written in English, belonging to formal literature (only papers published in journals) and that, after the reading of the text, still belong to the PSS topic. After data selection, systematic review employs data extraction and research synthesis helps in summarizing the findings. We employed statistical analysis and reported its results in the "Descriptive findings" section.

Table 1: Database search criteria

Electronic Database	Scopus

Subject area	Business, Management and Accounting Engineering Decision Sciences Environmental Sciences Economics, Econometrics and Finance
Search words	"product service system*" "product-service system*"
Field	Title, Abstract, Keywords
Manual filters: criteria	• Only papers in English with title, author, publication year, source. • Only papers dealing exclusively with PSS. • Exclusion: editorials, books review, books, conference papers.

3. *Reporting and dissemination*. We produced a two-stage report, subdivided in "descriptive analysis", reporting meta-analysis and statistical analysis, and "thematic analysis", in which we examined in detail the main topics, research fields and sub-fields.

We structured our review following these guidelines obtaining 342 articles covering the period from 2000 to 2016. A selection based on title and abstract lead us to a restricted set of 246 articles, which became 210 after a selection based on full text analysis; then, employing citation analysis, we retrieved another 14 articles, achieving a final set of 224 core articles from 1988 to 2016 dealing with the PSS topic.

3.3.Structures from literature

After discussing the main descriptive and thematic findings emerging from the analysis, we tried to develop a classification including and describing the different characteristics of the works examined. We decided to code the papers according to two different and separate criteria:

- *Criterion 1:* a coding criterion based on methodology and research purpose. According to the methodology employed, we distinguished papers in: *Conceptual study, Literature review, Case study, Action research, Survey*. According to the purpose: *Description, Exploration, Theory building, Theory testing, Theory refinement*. This framework will be presented in Section 4.
- *Criterion 2:* a content criterion. Moving from the *RQ4*, we adopted a two-dimensional classification: the presence (or absence) of an *economic analysis* of PSS, and the presence (or absence) of an *environmental/social analysis* of PSS. We charted these features among main topics retrieved through papers. Then these two dimensions of analysis were converted into the axes of our framework, providing a four-group classification scheme for the papers examined. This conceptual framework will be presented in Section 6.

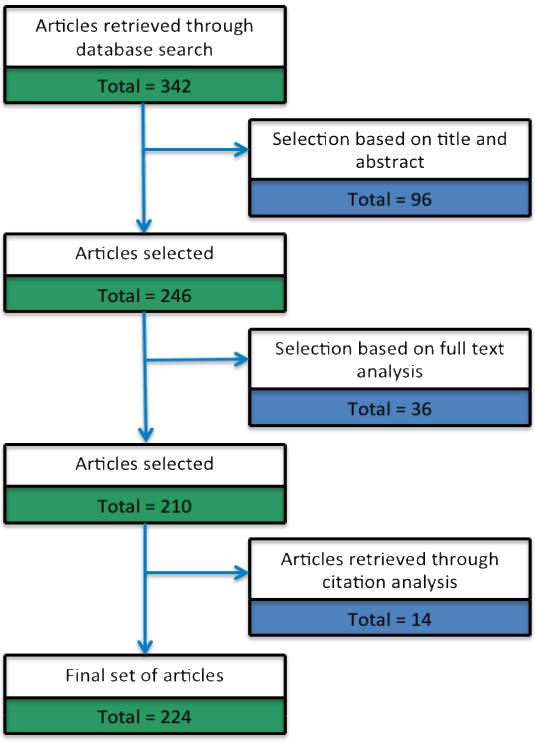

Figure 1 – Literature selection process

4. Descriptive findings

The set of 224 papers covers a time-period that spreads from 1988, with the oldest article by Vandermerwe and Rada, to 2016, with the most recent article published by Tran and Park. The years with the highest numbers of works published are 2012 and 2013.

Articles dealing with PSS show a rising trend, except for 2006 (Figure 2). The relatively large number of papers published in that year is partly due to some EU projects ending in that period and partly due to a special issue of the Journal of Cleaner Production. The trend can be explained because of a renewed interest in services, in their management and in possibilities they can offer to new market development (also indicated as one of the main benefits by the papers analysed). Moreover, thanks to a wide spread and improvement of ICT, many new possibilities were discovered during recent years, increasing the chances to exploit new technologies combined with services. It could be interesting to note that during 2012 Computers in Industry dedicated an entire issue (No. 4) to PSS and, as a result, concern with PSS spread also among journals and authors from the ICT research area: more than 50% of papers with a clear focus on ICT (Table 5, Figure 3) were published between 2012 and 2015. Also the Journal of Cleaner Production published a special issue in 2015 focused on Sustainable PSS.

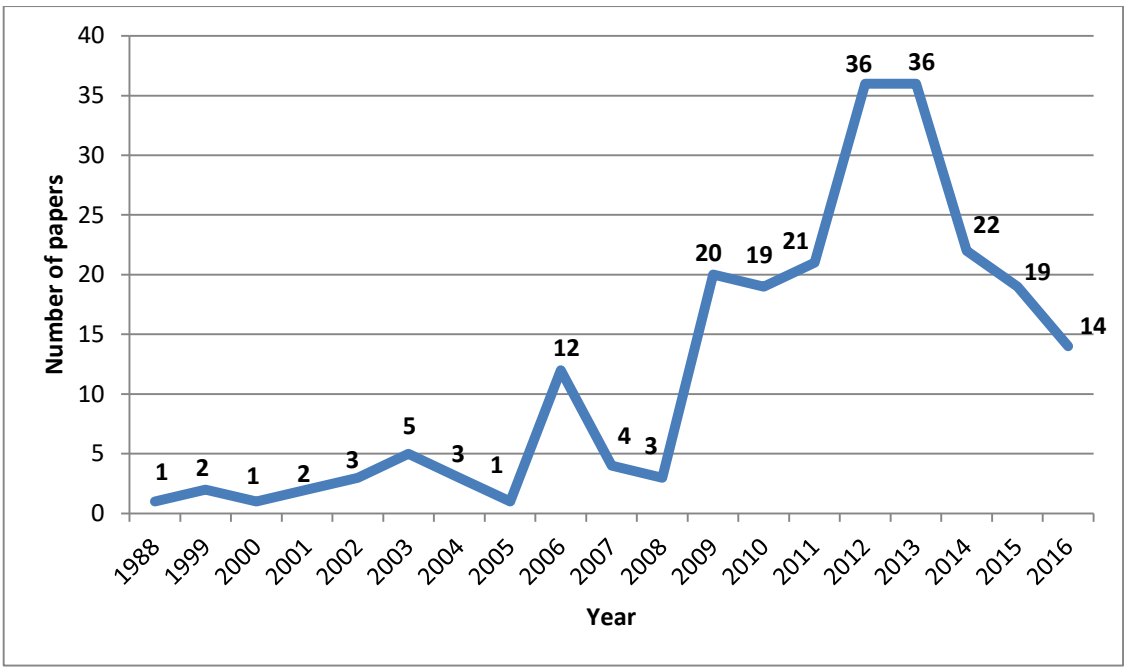

Figure 2 - Time trend of articles about PSS

Table 2 reports the list of Journals where two or more papers appeared: the average Impact Factor is 1.699, where Journal of Cleaner Production presents the highest one (3.844) and Service Business the lowest one (0.645). Table 2 shows the subject areas covered by each journal, considering that each one may cover more than one subject area. Business, Management and Accounting is the first subject area per number of articles, followed by Engineering, Decision Sciences and Computer Science: the last one, although if not included in the initial search, emerged in association with the ones selected, showing, together with the area of Engineering, also an interest in technical and technological aspects mainly linked to PSS development and design. Environmental science is not the main subject area about PSS: although the topic has been introduced with a close relationship with research on sustainability, during the years it attracted attention from many different research areas, as demonstrated also by many different journals where publications appeared.

Table 2 - Journals with two or more published papers on PSS

Journal	Subject area	Impact Factor	No.
Journal of Cleaner Production	Business, Management and Accounting; Energy; Engineering; Environmental Science	3.844	52
Journal of Manufacturing Technology Management	Engineering; Decision Sciences; Business, Management and Accounting	2.106	15
International Journal of Production Research	Business, Management and Accounting Decision sciences; Engineering	1.477	14

CIRP Journal of Manufacturing Science and Technology	Engineering	-	9
International Journal of Advanced Manufacturing Technology	Computer Science; Engineering	1.458	9
Computers in Industry	Computer Science; Engineering	1.287	9
International Journal of Operations and Production Management	Business, Management and Accounting; Decision Sciences	1.736	6
CIRP Annals – Manufacturing Technology	Engineering	2.542	5
Journal of Engineering Design	Engineering	1.036	5
Expert Systems with Applications	Computer Science; Engineering	2.240	4
International Journal of Computer Integrated Manufacturing	Computer Science; Engineering	1.012	4
Computers and Industrial Engineering	Computer Science; Engineering	1.783	3
Ecological Economics	Economics, Econometrics and Finance; Environmental Science	2.720	3
International Journal of Internet Manufacturing and Services	Computer Science; Decision Sciences; Engineering	-	3
Journal of Intelligent Manufacturing	Computer Science; Engineering	1.731	3
Service Business	Business, Management and Accounting	0.645	3
Business Strategy and the Environment	Business, Management and Accounting; Environmental Science; Social Sciences	2.542	2
Design Studies	Arts and Humanities; Computer Science; Social Sciences; Engineering	1.304	2
European Management Journal	Business, Management and Accounting	1.222	2
International Journal of Product Development	Business, Management and Accounting; Economics, Econometrics and Finance	-	2
International Journal of Services Operations and Informatics	Business, Management and Accounting; Computer Science; Decision Sciences	-	2
International Journal of Technology Intelligence and Planning	Business, Management and Accounting; Decision Sciences	-	2
Journal of Design Research	Computer Science; Engineering	-	2
Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture	Engineering	0.954	2
Sustainability	Energy; Environmental Science; Social Sciences	1.343	2
Research Technology Management	Business, Management and Accounting; Engineering	1.017	2

Table 3 reports the methodological framework. Case studies and conceptual studies represent the great majority of papers: 63% of case studies and 69% of conceptual studies are focused on theory building, which is the main research purpose among PSS domain (59% of total papers), followed by exploration and theory refinement. It is interesting to note that some literature reviews are used to

support theory refinement and for explorative purposes and they are not limited to a plain descriptive research aim, but are used as a method to support other theories and results. Data also shows a lack of survey methodologies and theory testing works, a lack that, surprisingly, is not even evidenced by future methodologies needed (as shown in the Future Directions paragraph).

Table 3 – Methodological structure

	Action research	Case study	Conceptual study	Literature review	Survey	Survey/Case study	TOT
Description		0,4%	0,9%	4%	0,4%		5,8%
Exploration	0,4%	16,5%	4,5%	0,9%	0,9%	0,9%	24,1%
Theory Building	1,8%	37,1%	18,8%				57,6%
Theory refinement	0,4%	4,5%	3,1%	3,1%			11,1%
Theory testing					1,3%		1,3%
TOT	2,7%	58,5%	27,2%	8%	2,6%	0,9%	100%

5. Thematic findings – PSS topics

5.1.Definition of PSS

Literature provides several definitions of PSS, each one focusing on particular aspects and/or characteristics. Mont (2002) focuses on the concept of system of products and services, together with the aim of fulfilling clients' needs and being competitive; some other authors underline the shift of the offer to intangibility (Tukker, 2004), the presence of networks (Mont, 2002) and/or the effects on environment (Manzini *et al.*, 2001). One of the most cited definitions is the first one given by Goedkoop *et al.* (1999), who stated that a PSS is "a marketable set of products and services capable of jointly fulfilling a user's need". Together with this one, the first definition to associate PSS and sustainability was given by Mont (2002): "a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models".

113 papers (50% of the panel) do not report a definition of PSS (neither giving one on their own nor citing other works), while 19 papers (8%) give an original definition of PSS, and 92 (41%) cite one of these (some papers report more than one definition): the most reported definitions are those by Mont (2002), cited 28 times, Baines *et al.* (2007), cited 23 times, Goedkoop *et al.* (1999), cited 28 times, and Tukker (2004), cited 13 times.

Table 4 – PSS definitions

Author(s)	Definition	Main aspects in definitions					
		Concept of system	Market propositi	Tangibili ty and	Also networks	Effect on environm	Social aspects
Goedkoop et al., 1999	A marketable set of products and services capable of jointly fulfilling a user's need. The PS system is provided either by a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment.	x	x				
Manzini et al., 2001	A business innovation strategy offering a marketable mix of products and services jointly capable of fulfilling clients' needs and/or wants - with higher added value and a smaller environmental impact as compared to an existing system or product.		x			x	
Mont, 2002	A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models.	x	x		x	x	
Manzini, Vezzoli, 2003	A product service system (PSS) can be defined as "an innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands".	x	x				
Tukker, 2004	A system consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.	x	x	x			
Halme et al., 2006	Products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy.		x			x	
Krucken., Meroni, 2006	An advanced industrialised solution based on collaboration between social players, which gives rise to both effective and efficient, highly contextualised services.						x

Morelli, 2006	A social construction, based on “attraction forces” (such as goals, expected results and problem-solving criteria) which catalyse the participation of several partners. A PSS is a result of a value co-production process within such a partnership. Its effectiveness is based on a shared vision of possible and desirable scenarios.						x
Baines et al., 2007	A market proposition that extends the traditional functionality of a product by incorporating additional services.		x				
Evans et al., 2007	An attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services.		x			x	
Azarenko et al., 2009	Technical Product-Service System emphasises the physical product core enhanced and customised by a mainly non-physical service shell the investment character of all PSS components, the relatively bigger importance of the physical core of PSS and the relation between PSS manufacturers and customers.	x		x			
Neely, 2009	A Product–Service System is an integrated product and service offering that delivers value in use		x				
Jiang, Fu, 2009	Industrial PSS can be defined as a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life-cycle.	x		x			
Meier et al., 2010 (a)	An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system.	x					
Zhu et al., 2011	PSS is defined as a solution for optimal resource operations in product life cycle through integrating tangible products with intangible services.			x			
Geng, Chu, 2012	Products and services are integrated and provided as whole set to fulfill customer's requirements, and the product/service ratio can vary in different customer using contexts.	x	x				

Boehm, Thomas, 2013	A Product-Service System (PSS) is an integrated bundle of products and service which aims at creating customer utility and generating value.	x	x				
Centenera, Hasan, 2014	A product-service system (PSS) is an integrated combination of products and services for optimal consumption.	x				x	
McKay, Kundu, 2014	A PSS is a system composed of a physical product and associated services that support the product through-life.	x					

We identified the main aspects of definitions and reported them in Table 4: "Market proposition/Customer needs" and "Concept of system" are the main aspects of PSS reported by citations, respectively 111 and 90 times (considering original definitions and their citations); then we have "Effect on environment" (33), "Networks and infrastructures" (29), "Tangibility and intangibility" (17), "Social aspects and partnership" (3). These statistics confirm that, even though PSS started its development linked to sustainability and environmental aspects, nowadays these are no longer the most influent aspects of this research stream.

Indeed, pulled by a main interest in the strategic value of PSS, literature is focusing more and more on those aspects connected to this sub-field, also because of the growing importance of raising customer acceptance of PSS. This is the case, for example, of sharing economy business models, where the concept of sharing is applied in different fields like the mobility sector (car-sharing, bike-sharing) and/or in hospitality and tourism (AirBnB and similar businesses): in these cases investigating elements connected to strategy and decision making, related to the issue of raising customer acceptance so as to win initial resistances to new offerings, is of great importance for both practitioners and scholars.

Indeed, especially in sharing economy and collaborative consumption models, customer acceptance is one of the main concerns because of the important shift operated in consumption schemes, focused on usage rather than on possession. That is why companies proposing these new offerings had to win resistance to change through low prices, free trials and free entry (no registration fee) strategies, like the case of car2go, Daimler's car-sharing offering. Another important element in the case of vehicles (cars, bikes, scooters), sharing proved to be the ease in finding, taking, and leaving means of transport almost everywhere, without the constraint of using only dedicated parking space: especially in car-sharing examples, this feature represented a major incentive for new customers, making the use of shared vehicles an actual and practical alternative to private cars/scooters.

"Concept of system" means that many definitions do not look at PSS as some products and services simply "put" together, but they constitute an offering where boundaries between physical and non-

physical components are blurred (Tukker, 2004; Meier *et al.*, 2010a). Following Tukker (2004), several authors also pointed out the tangible/intangible nature of the PSS offering (Azarenko *et al.*, 2009; Jiang and Fu, 2009). Obviously many definitions focus on the economic and commercial advantages provided by PSS ("market proposition/customer needs") - Goedkoop *et al.* (1999) and Manzini and Vezzoli (2003) - and/or on the environmental/social benefits expected ("effect on environment", "social aspects") - Mont (2002) and Halme (2006). "Networks and infrastructures" is a particular aspect evidenced by Mont (2002), who stresses a very important aspect of PSS nature, which can reach its full potential only if designed and implemented by a series of firms constituting a focused supply chain (Aurich *et al.*, 2006; Bankole *et al.*, 2012).

Therefore, our complete definition is: *PSS is a business model focused toward the provision of a marketable set of products and services, designed to be economically, socially and environmentally sustainable, with the final aim of fulfilling customer's needs.*

5.2.PSS main current research streams

Figure 3 represents the main focus (we assigned only one focus to each article). We used this evidence to identify and characterize main research streams among PSS research domain.

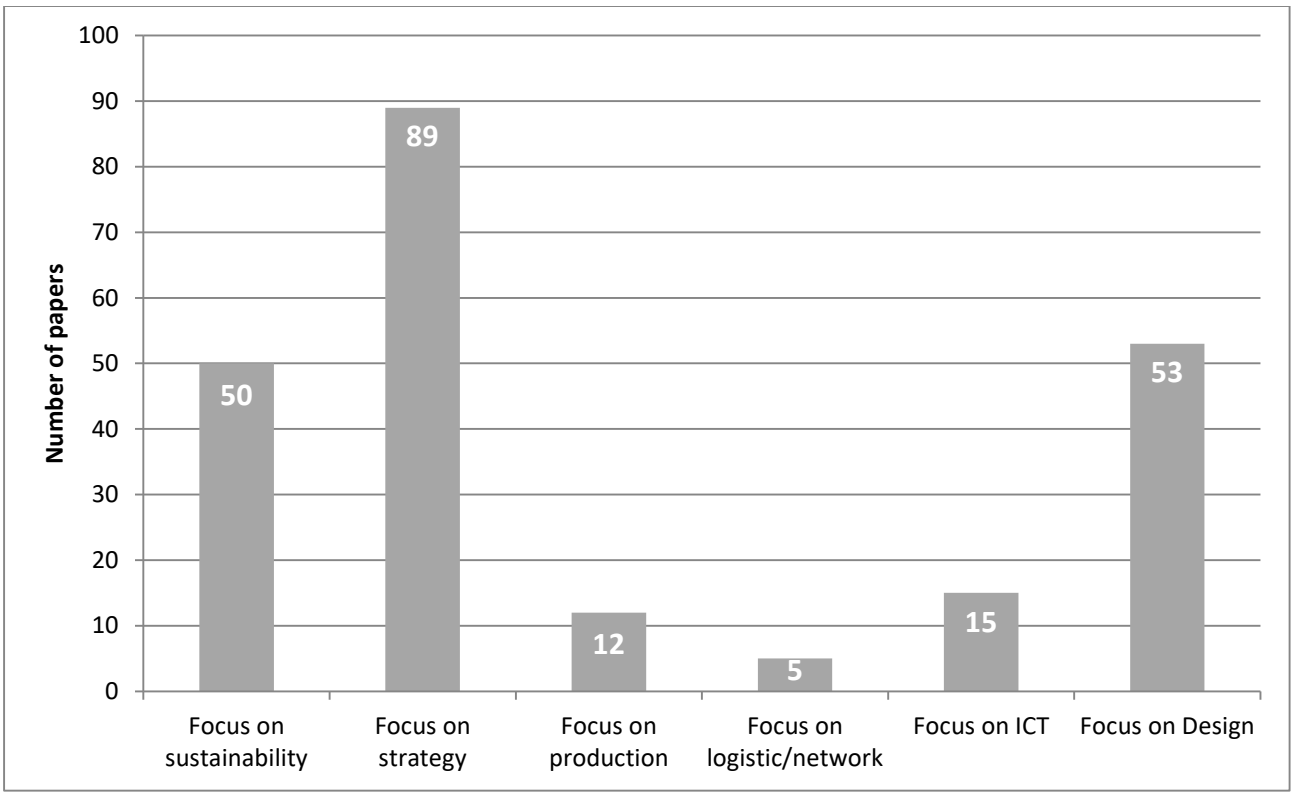

Figure 3 – Number of papers by area of focus

Sustainability emerged as the principal topic about PSS from its start until present day (Roy, 2000; Mont, 2002), but is losing its main role among research fields, though it does remain important. The sustainability goal can be reached through PSS in different ways: reuse and recycling of products at the end of their life cycle, which is a concept that can be applied to several business models, like office furniture (Besch, 2005), construction machinery industry (Dongmin *et al*., 2012), manufacturing (Igba *et al*., 2015); maintenance services to lengthen products' useful life and reduce change rate, a potential that can be fully exploited in manufacturing (Meier *et al*., 2010a; Huang *et al*., 2011); forms of leasing, sharing and/or pooling in order to maximize consumption rate by allowing multiple use, leaving to the provider the ownership and maintenance of the product (Mont, 2002; Tukker, 2004).

From the analysis of some recent articles, we discovered two emerging research fields: *business models* (Reim *et al*., 2015) and *collaborative consumption* (Piscicelli *et al*., 2015).

Mont (2002) defined first the PSS as a business model. Reim *et al.* (2015) conducted a detailed and well-structured theorization of PSS as a business model. The three categories universally accepted (product-oriented, use-oriented, result-oriented) could be considered as business models, each one corresponding to different sets of tactics that could be implemented by organizations. Although Reim *et al*.'s contribution gave a new importance to this stream of research, other papers in previous years examined PSS as an entire business model, and not only as a simple offering composed of a mix of products and services, like Isaksson *et al.* (2009), De Coster (2011), Overholm (2015).

Collaborative consumption is an economic and cultural model based on access to products rather than on their exclusive possession (Piscicelli *et al*., 2015). In recent years, businesses based on collaborative consumption have become increasingly more common and numerous. A complete exploitation of this business model can be achieved with the use-oriented category of PSS: this is the case of car sharing systems, like car2go, whose sustainability potential (in environmental terms) was analysed by Firnkorn and Müller (2011, 2012) through case studies; another example can be that of bike sharing, examined in detail by Zhang *et al.* (2015) through a case study conducted in China.

5.3.Main topics

In Table 5 we report the main topics retrieved in the selected papers. Two of the less studied topics are the economic analysis (16% of papers) and the social/environmental analysis of PSS (15%) confirming the aim of this research.

The topic "Applications of PSS" is the most common: a paper provides one or more examples about how a PSS has been developed and/or implemented. Following, another important topic is "Characteristics of PSS": the author(s) lists a series of PSS characteristics/elements.

A contribution on "PSS development/design" provides a series of tools, methodologies and/or guidelines about PSS design process. The high number of contributions dealing with this aspect highlights the great attention attracted by this topic, as evidenced also by the "Focus on design", which is the second category per number of papers. This sub-field of research is closely related to the investigation of methods for an effective and efficient design of PSS, e.g. Morelli (2002a, 2002b, 2006, 2009), Bertoni *et al.* (2011, 2013) and, more recently, Joore and Brezet (2015). Another major issue concerns product innovation and different models of sustainable PSS (Roy, 2000). Works belonging to this research stream mainly focus on the manufacturing industry and B2B market, e.g. Azarenko *et al.* (2009), or focus on the oil & gas industry, e.g. Bandinelli and Gamberi (2012). Other articles belonging to this group focus on alternative approaches to PSS design, e.g. Kimita *et al.* (2009) who consider customer satisfaction as a key element in the process of PSS design.

A paper deals with "PSS model" if it proposes a framework about PSS representation, description, evaluation. The most important and cited papers dealing with this topic are those by Goedkoop *et al.* (1999), Mont (2002), Aurich *et al.* (2006, 2009).

A shared consensus has been reached on PSS categories: product-oriented, use-oriented and result-oriented services (Tukker, 2004). In the first category, the main offering still consists of products, but some extra services are added. In the second one, the ownership of product remains of the provider/seller and is made available to users, who pay for its use and not for possession. In the third category, the actors (provider and client) agree upon a result, without any or with few predetermined conditions.

Table 5 – Main topics

Main topics	**No. of papers**
Applications of PSS	142
Characteristics of PSS	130
PSS development/design	126
PSS model	65
Benefits	41
Barriers	37
Economic analysis	35
Social/environmental sustainability analysis	34
Drivers for PSS	24
Categories of PSS	22

5.3.1. PSS benefits

Scholars agree upon the main benefits that the implementation of a PSS could provide, reported in Figure 4. We refer to those papers (40, 18% of total panel) that explicitly dealt with PSS benefits. We

can see that papers dealing with this topic are not a great amount and they do not seem to show any particular trend connected with time. Mont (2002) is the author who identified the highest number of benefits (8), while Lelah *et al.* (2011) reported only one benefit. The mean number of benefits identified by each author is 4.

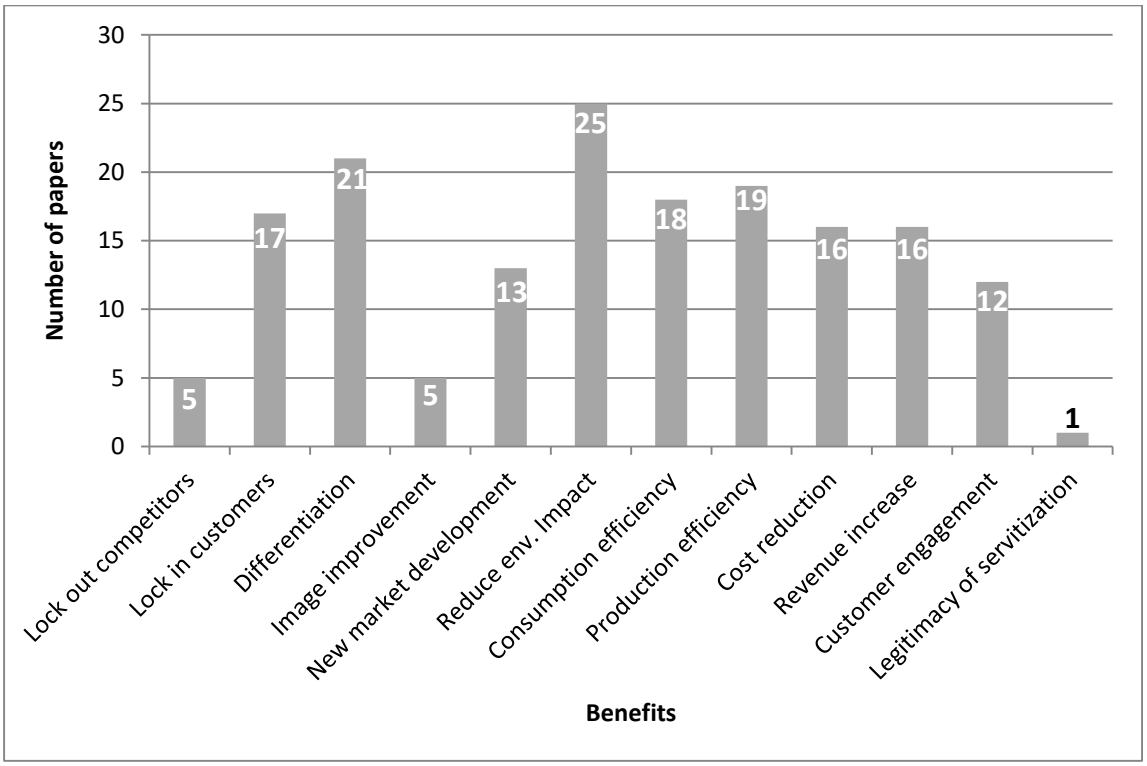

Figure 4 – Histogram of PSS benefits

The most frequently recognized benefit (62% of the articles) is the reduction of environmental impact, which is also one of the main reasons behind the development and implementation of a PSS (Goedkoop *et al.*, 1999; Williams, 2006); many times this benefit is also recognized in conjunction with "Image Improvement" (Wagner *et al.*, 2013; Gelbmann and Hammerl, 2015).

Differentiation is also an important benefit, as stated by Baines *et al.* (2007): "PSS is claimed to provide strategic market opportunities and an alternative to standardization and mass production. The fundamental benefit is an improvement in total value for customers through increasing service elements." An example of such opportunities was provided by Mont in its editorial opening the special issue (2003) of the Journal of Cleaner Production focused on PSS and sustainable consumption, where she reported an overview of the Organisation for Economic Co-operation and Development (OECD), indicating that "in areas such as household energy use, travel and waste generation, material and energy efficiency gains have been outweighed by the absolute increase in the volume of goods and services that are consumed and discarded." PSS allows firms to de-couple

economic growth from environmental pressure while satisfying consumers' needs, constituting an important strategic market opportunity.

Other authors pointing out this benefit are Becker *et al.* (2008), Sundin *et al.* (2010), Dimache and Roche (2013). Following this argumentation, not surprisingly, another important benefit is that of "Locking-in customers" (strictly connected with "Customer engagement"), which was recognised first by Vandermerwe and Rada (1988) and Wise and Baumgartner (1999), the latter stating that "in the new world of manufacturing, the sturdiest barrier to competition is customer allegiance. The goal is not necessarily to gain the largest share of customers but to gain the strongest relationships with the most profitable customers." Authors also provide the example of Xerox, highlighting how it succeeded in emphasizing the role of services sold in reducing expenses and total-labour costs for clients (Wise and Baumgartner, 1999).

PSS also has the potential to restrain competitors, thanks to an innovative offering that can hardly be imitated because of its unique nature (this observation is even more as customization degree grows). Following this reasoning, the benefit named "Locking-out competitors" should be complementary to "Locking-in customers", but only five articles considered it. The reason behind the major importance given to customers rather than competitors is probably contained behind a phenomenon that Turunen and Finne (2014) defined as "Legitimacy of servitization": they discovered a "U-shaped relationship between population (of firms dealing with PSS) density and exit rates, and an inverse U-shaped relationship between population density and entry rates."

Other important benefits are those regarding "Consumption efficiency" and "Production efficiency", which are always cited in pair (Cook *et al.*, 2006; Armstrong *et al.*, 2015): PSS is conceived and designed so as to prolong products' life cycle and utility, in order to allow a better exploitation of resources and less waste production. Prolonged life span of products leads to greater efficiency during the consumption phase from the customers' perspective. Moreover, adding services to a product may also introduce advantages from the producer's perspective, because through the implementation of reuse & recycling policies, many components and parts could be remanufactured, reutilized and recycled into new products, which is clearly more sustainable (economically and environmentally) than producing entirely new components.

Most times, together with these two benefits, we can also find "Cost reduction" (Goedkoop *et al.*, 1999; Heiskanen and Jalas, 2003). Together with differentiation, we have the following benefit of "Revenue increase", due to the higher value gained by the offering through PSS, and due to the lower impact of costs through life cycle, also thanks to remanufacturing and reuse of components. Furthermore, there is also the possibility of developing new market opportunities for companies, as well as help in formulating policies to promote sustainable patterns of consumption from the government perspective (Manzini *et al.*, 2001).

5.3.2. PSS barriers

As for barriers, the main one that has been widely recognized is the necessity of a cultural shift for both the producers and customers, expressed by: "Acceptance from customers" and "Shift in companies' culture/resistance to change" (Mont, 2006a; Sakao *et al.*, 2013). From the producers' perspective, a change in their organizational culture and conception of business value should occur; considering the customers' point of view, the main drawbacks are related to the shift in their consumption habits and schemes, especially for what regards use-oriented and result-oriented categories of PSS (Mont, 2002; Ceschin and Vezzoli, 2010). Following these two main barriers, we must also consider "Acceptance from stakeholders", especially for those belonging to the supply chain of the servitized firm, whose support is fundamental for PSS development and on-going management: cooperation deriving from commitment to PSS is a key element for a win-win-win strategy (supplier-producer-customer). Besides, authorities also need to be considered, as they play a very important role in PSS acceptance and spread through the market (Mont and Lindqvist, 2003; Hannon *et al.*, 2015).

Other important barriers are "Lack of technological info and know-how", "Lack of experience in service design" and "Lack of skilled personnel in service development" (Barquet *et al.*, 2013; Kastalli *et al.*, 2013): "education and training should be carried out for technical personnel, service personnel, and retailers at the initial establishment stage. Retailers need a combination of education, training, and information systems for settling the problems faced by customers" (Kuo *et al.*, 2010). The shift to PSS requires "A social system or infrastructure that would accept or support the suggested product–service scenario. If such a system does not exist, a completely new infrastructure or network might need to be designed" (Mont, 2002). Filling these gaps can bring higher and higher cost generation, due to the necessity of hiring skilled personnel, or due to the "Lengthening of time to market", recognized as a direct consequence and as an additional barrier by Ceschin and Vezzoli (2010); as Mont (2002) pointed out, "adding environmental considerations to the product development cycle is often seen as lengthening the time to market. This is even more so if the PSS design is focused on environmental efficiency."

"Lack of profitability/market" is a major obstacle to PSS implementation (Wise and Baumgartner, 1999): "you should look at such indicators as the ratio of installed units to annual new-unit sales, the customer's usage costs over the product life cycle relative to the product's price, and the profitability of downstream activities relative to product margins."

Another important barrier, related to the environmental issue, is the so-called "Rebound effect": "studies conducted reveal that multiple use does not automatically lead to lower impact on the

environment. The environmental impact depends, to a large extent, on the circumstances, schemes and conditions of use." (Mont, 2002) That is why some consumption schemes, based on the absence of ownership for the consumers like sharing and leasing, can lead to an unsustainable use of products and assets by the same consumers, bringing environmental disadvantages rather than advantages.

Last but not least, also "Legitimacy of servitization" is a barrier, because depending on the contingent situation of the industry it can be a benefit or a barrier (Section 5.3.1).

As for the benefits, the author who reported the highest number of barriers (7) is Mont (2002), together with Allen Hu *et al.* (2012) and Hannon *et al.* (2015), while Wise and Baumgartner (1999) cited only one barrier. The average number of barriers identified by each author is 4.

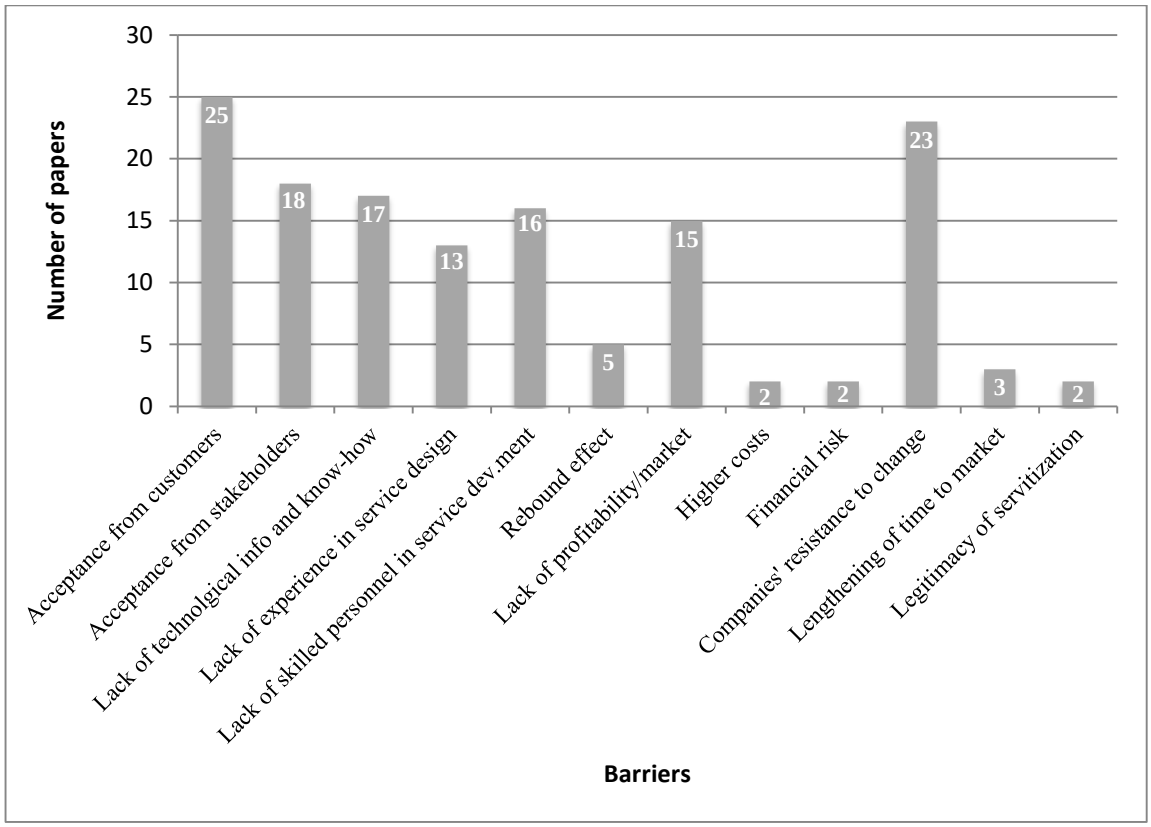

Figure 5 – Histogram of PSS barriers

5.3.3. PSS drivers

Drivers can be considered as the motivations underlying the decision of developing/implementing a PSS. Most of these drivers relate to marketing, like "Building relationships with customers" or "Extending existing offer" (Azarenko *et al.*, 2009; Wagner *et al.*, 2013): customer involvement, engagement and allegiance are crucial elements in establishing a successful PSS offer. We could say the same about "Extending existing offer", which is strictly related to the benefits of "Differentiation" and "New market development": organizations strive to reach a strong position in the customers' market, thanks to new innovative offerings like PSS, which is also difficult to imitate for competitors;

furthermore, an extension in the total offering (intended as new additional services or entirely new systems) can be a powerful means to restrain even more loyal customers and acquire new ones.

Other drivers are particularly related to the dimension of strategic analysis, like “Searching for USP” and “Discouraging newcomers” (Rese *et al.*, 2009; Roy and Cheruvu, 2009): as already stated, PSS requires the introduction of a new business model, focused on the provision of a new kind of offering to customers, a Unique Selling Proposition, which can constitute a strong competitive advantage, and could position the firm on a higher step in the market, linking this aspect to benefits like “Differentiation” and “Lock-out competitors”. At the same time, traditional business models focused on product selling, could be easily copied and reproduced by competitors, acting in the same market or also coming from other markets (newcomers) and sectors attracted by new possibilities (“New market development”): PSS and the high level of customization allowed by service components, have been recognized as an effective way of containing and contrasting this phenomenon (Goedkoop *et al.*, 1999).

“Cooperating with authorities” and “Reducing environmental costs” are strictly connected to the social and environmental aspects of sustainability, allowing for the anticipation of the implications of future take-back legislation (Goedkoop *et al.*, 1999). “Availability of various models of PSS” regards the chance for the organization to best meet customers’ needs through implementing one or more categories of PSS (Mont, 2004). Other drivers are related to production and logistics aspects, like “Best utilisation of assets”, “Remanufacturing vs. producing” and “Supplier engagement” (Azarenko *et al.*, 2009; Lockett *et al.*, 2011).

The most cited drivers (respectively 11 and 10 times) are “Building relationships with customers”, “Cooperating with authorities” (Mont and Lindqvist, 2003; Hannon *et al.*, 2015), “Extending existing offer”, “Reducing environmental cost”, “Best utilisation of assets” (Mont, 2004; Centenera and Hasan, 2014) cited 9 times each; the papers reporting the highest number of drivers are those by Goedkoop *et al.* (1999) and Azarenko *et al.* (2009), while Sundin *et al.* (2009) report only one driver (“Remanufacturing vs. producing”).

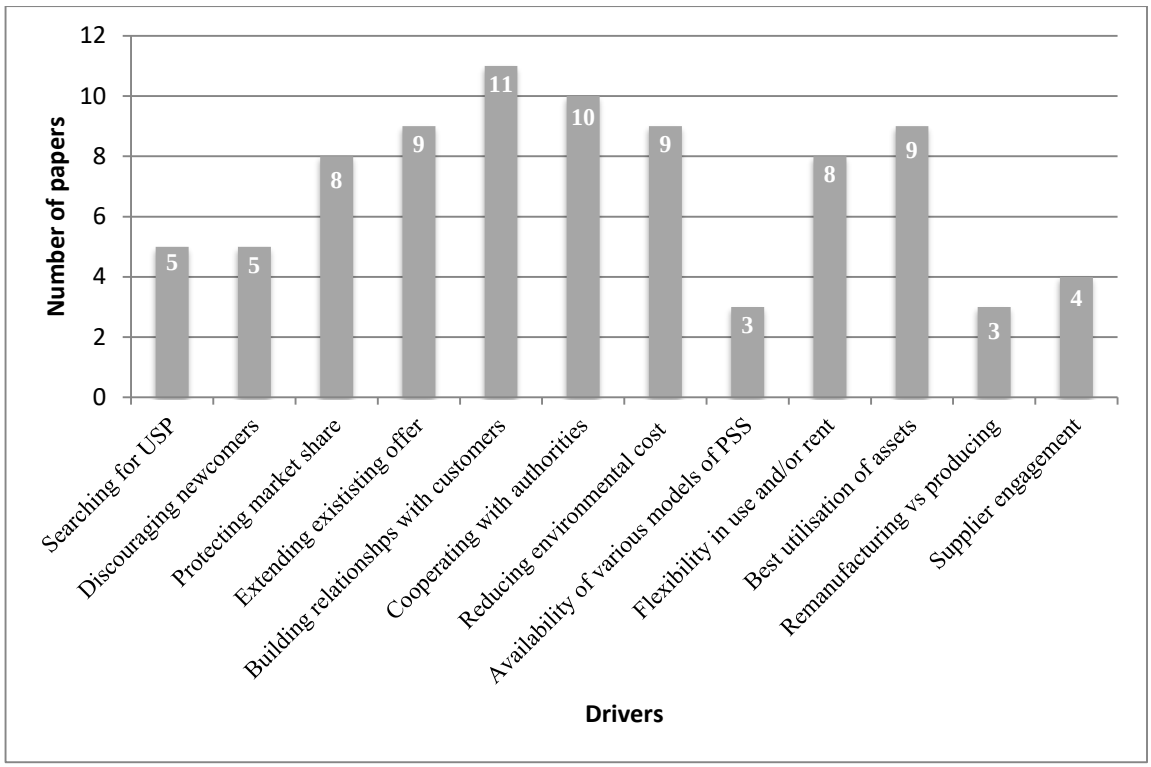

Figure 6 – Histogram of PSS drivers

6 Conceptual structure

This section investigates the aspect of economic/environmental/social impact of PSS. We charted the main topics (Table 5) of papers providing an economic analysis and/or an environmental/social analysis: we grouped together the last two aspects because the social impact of PSS is in almost all cases analysed together with the environmental aspect.

We distinguished papers in four separate categories: “Economists” providing only an economic assessment of PSS potential; “Environmentalists” dealing exclusively with the environmental/social analysis; “All-Around” providing both analyses; “Designers” writing about neither the economic nor the environmental/social analysis. These four groups have been represented in the graphic below (Figure 7). We depicted the main focuses (Table 5) inside every group by means of bubbles, with sizes representing the percentages of papers.

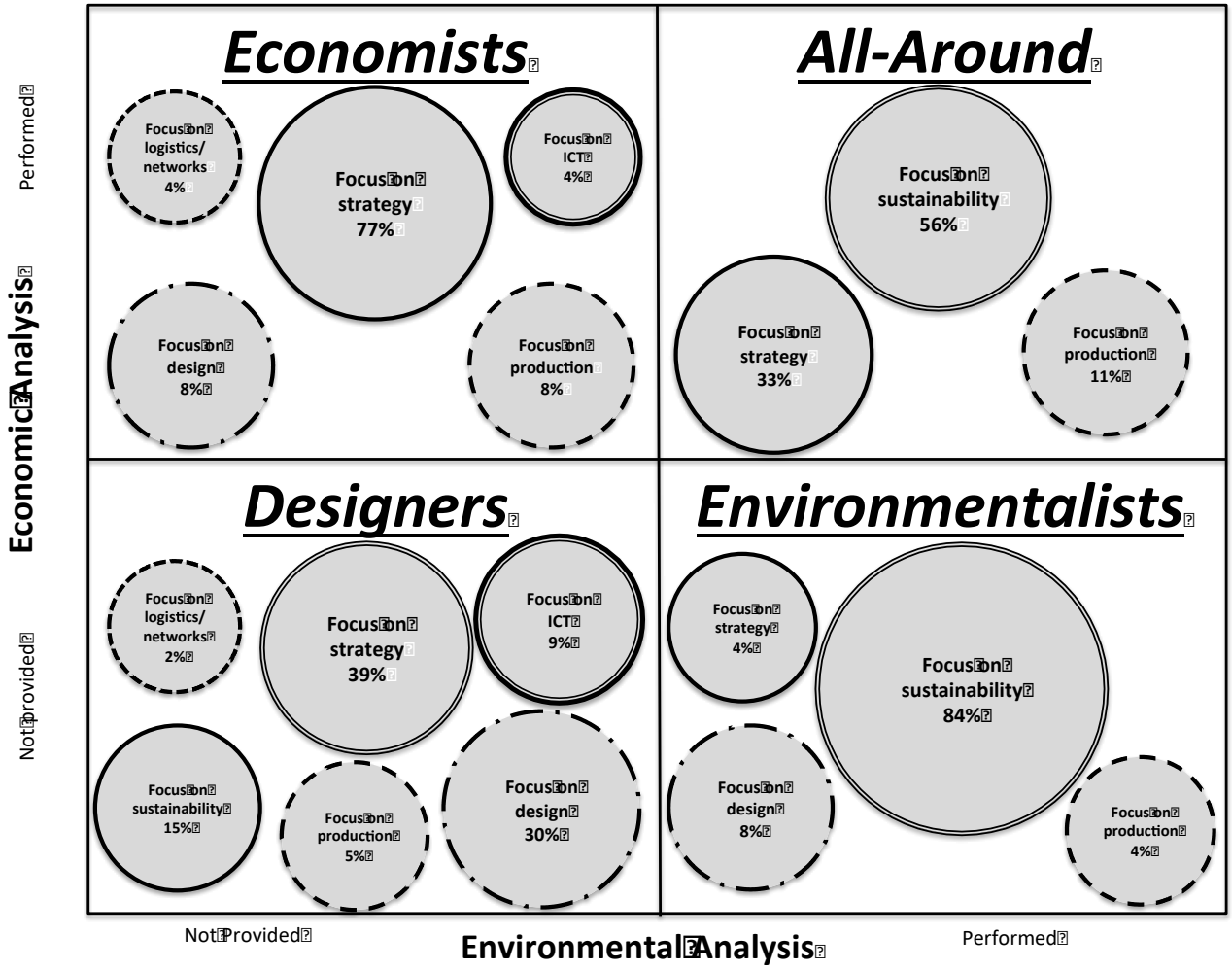

Figure 7 – Conceptual structure

Economists. Each of the 26 papers in this group provided an analysis of PSS economic potential, mainly in quantitative terms. From a time trend perspective, papers belonging to this group show a rising trend starting from 2009 to 2012, with a peak of works that diminishes a little in 2013 and 2014. The great majority of papers (20 on 26, 77%) is focused on the strategic value of PSS; evidence that appears to be consistent with expectations of this group (economic analysis/evaluation most of times derives from strategic considerations). 16% of papers are focused respectively on production (8%) and on design (8%), while the remaining 8% is focused on logistic/networks (4%) and on ICT (4%). None of the papers belonging to this group has a focus on sustainability. The most recurring topic is "characteristics of PSS", followed by "PSS development/design" and "applications of PSS".

Looking at this group, we can see how the economic analysis of PSS is carried out in several ways, with different methodologies. Azarenko *et al.* (2009) propose a cash-flow analysis for a machine tools provider, forecasting for the following twenty years the expected economic benefits of PSS, and using this analysis to compare the product-oriented, use-oriented, and result-oriented categories, in terms

of monetary results. Similarly, other authors (Nishino *et al.* (2012), Kreye *et al.* (2014)) mainly focus on cost estimation, trying to evaluate the transition to PSS in a meaningful quantitative way.

Richter *et al.* (2010) provide an economic analysis in order to appraise in quantitative terms the evolution of business models when employing PSS: the analysis is performed only for the use-oriented category, with the aim of estimating changes in costs, revenues and profits comparing the servitization alternative with cost-plus and fixed-price contracts, showing that the PSS is a win-win situation for customer and supplier.

Neely (2009) compares firms on the bases of their sizes and focus (purely manufactured vs. servitized organizations), obtaining interesting results: servitized firms tend to generate higher revenues but lower profits compared to pure manufacturing firms, and this is true for larger firms; while for organizations with less than 3000 employees this finding is completely inverted. This is called *the paradox of servitization* (Neely, 2009). Finally Friebe *et al.* (2013) explore low-income markets in the context of solar home systems, evaluating the economic potentials of PSS. Komoto *et al.* (2012) show how the economic analysis of PSS can be implemented in the design phase, improving the design process and overall performance.

Environmentalists. There are 25 papers dealing with the environmental/social analysis of PSS. The first paper to deal with environmental/social analysis is dated 2003 (Maxwell and van der Vorst), and until 2011 the number of papers oscillates between one and two, with some years missing (2005, 2008, 2009); starting from 2012 to 2015 there has been a rise in the number of environmental/social analyses.

84% have a clear focus on sustainability, while other two papers are focused respectively on strategy and production, and the remaining two have a focus on design. Therefore, the analysis of environmental/social impact can be linked to sustainability and strategic aspects. Differently from the previous group, here the main topic retrieved is “applications of PSS”, so we suppose that there is a more pragmatic/empirical aim behind papers providing an analysis of social/environmental impact.

Going into detail in the papers, what first emerges is that this analysis is much more qualitative in nature than economic analysis. Dewberry *et al.* (2013), dealing with PSS design and development process, provide a framework for “Home life cycle” analysis, considering the four different phases of specification and sale, use, disposal, re-sale and use. Halme *et al.* (2004), in their work on the environmental/social assessment of household services, provide an “operazionatilization of sustainability indicators”, using a scale to assess impacts of PSS change. Maxwell and van der Vorst (2003) describe the features of a method for sustainable product and service development: they provide an overview of the overall process, and analyse how it can be incorporated into an organization’s processes and systems. Briceno and Stagl (2006) employ a survey methodology in order to investigate the PSS social effects of local exchange trading schemes; by surveying organisers

and participants, authors provide a clear overview on the effectiveness in social terms of these programmes. Evans *et al.* (2007) provide a very useful tool for assessing and representing "Environmental improvements for SME employee solution". In a more technical way, Tasaki *et al.* (2006) provide a quantitative method to assess material use and consumption level in "lease/reuse systems of electrical and electronic equipment". Firnkorn and Muller (2011), analysing car-sharing systems, deploy the system into processes, parameters and effects, in order to assess the overall environmental impact: their quantitative model employs a total number of 30 internal and external variables, ranging from kilometres driven, CO_2 emissions, fuel consumption.

All-Around. Only 9 papers belong to this category, confirming that it is rare to conciliate the two analyses together in a single work. Looking at years in which papers were published, there is no time trend emerging.

56% of papers have a focus on sustainability and 33% on strategy, with another paper focusing on production. Among topics, the most common is "applications of PSS". Following the main focus on the sustainability dimension, if we also consider that 78% of papers deal with PSS applications, we can state that, although both analyses are provided, there is still a prevalence of the environmental/social dimension for what regards the focus and the purpose (pragmatic/empirical).

Almost all studies in this group employ the same tools for economic and environmental analysis, because the two analyses need to be summarized together and there is little space for complex tools and methodologies of detailed analysis. Almost all studies employ Life Cycle Analysis to estimate environmental impact of products, services, and activities performed; sometimes this analysis is mixed or alternated with other qualitative tools. For the economic aspect the most employed tools are cost analysis, net present value as a forecaster of economic potentials, benefits/costs analyses and qualitative evaluations like the potential for new market development.

In this group the first work is that of Goedkoop *et al.* (1999) who present a very well defined methodology for assessing both the economic and environmental impact of PSS. They analyse the two dimensions qualitatively and quantitatively: first of all, they employ four axes to evaluate qualitatively four characteristics of PSS, including environmental and economic impact; for the first one, authors provide a detailed analysis of lifecycle impact. For products, they identify three main profiles: U-shaped form, with the environmental burden in production and disposal phases; I-shaped form, with environmental burden only in use phase; W-shaped form, where the environmental burden is caused in all three life stages. Qualitative analysis of economic impact is mainly focused on the evaluation of competitiveness in existing markets and in new potential markets, emerging from PSS introduction; this assessment of competitiveness takes into account both provider and client perspective. For the quantitative assessment of the economic impact, authors employ the profit pool analysis: "The key of a profit pool analysis is the composition of a graph in which all relevant

commercial activities in the business area of a company are plotted. For each activity, turnover is plotted on the horizontal axis and profit margin is plotted on the vertical axis. The profit pool clearly shows the places where money is being made." Similar to the profit pool concept, for the quantitative assessment the authors elaborate the concept of eco-pool, with the same structure of the previous one, and with y-axis plotting the environmental load, which was estimated for each activity using Life Cycle Analysis. Then, the two pools are joined in a single graph. Expressing both environmental and economic impact as a vector, and adding together all the activity vectors, it is possible to obtain a single vector (called E2 vector – Economic and Environmental) that summarizes in a single datum all the environmental and economic performances of PSS.

In his work, Tukker (2004) defines eight different types of PSS deriving from his categorization, and analyses them first of all under the economic/competitiveness aspect, evaluating for each of these types: market value for users, costs for provider, capital needs, and the ability to sustain value in the future. Then, for each type, the author evaluates the environmental/social potential in terms of impact reduction, considering mechanisms with incremental impact reduction (i.e. incremental efficiency improvement), mechanisms with average to high impact reduction (i.e. more intensive use of goods, less use of energy), mechanisms with very high impact reduction (i.e. application of radically low impact technology). Finally, the author estimates for each type of PSS the sustainability benefit that can be obtained (compared to the situation of pure product selling).

Designers. In this group we have the highest number of papers (162). This disproportion confirms what we stated in the previous sections of theoretical background and research aim: literature lacks a deep insight into the evaluation of PSS economic and environmental/social impact.

In this group the main focuses are on strategy (39% of papers) and on design (30%); "PSS development/design" is the most recurrent topic (65% of papers deal with it). Other main topics retrieved are "applications of PSS" and "characteristics of PSS". In this group we have seminal works on PSS, the most cited in literature, like those by Vandermerwe and Rada (1988), Roy (2000), Mont (2002), Manzini and Vezzoli (2003), Oliva and Kallenberg (2003), Baines *et al.* (2007) and Meier *et al.* (2010a): all these papers mainly provide a general overview on PSS characteristics and potentials, summarizing them in theoretical frameworks, with a clear theory building research purpose. However, the main sub-field of research that clearly emerges in this group is that of PSS design and development: also if many papers are focused on PSS strategic aspects, their final aim is that of providing guidelines, tools and/or methodologies for an effective PSS design process. Indeed, 40 of 63 papers focusing on strategy deal with PSS development/design, and the number is even bigger if we also consider papers from other focus areas dealing with design: this amount, added to the other 49 papers with a clear focus on design, clearly identifies the main stream of research in this group. Then we have works like those by Morelli (2002a, 2002b, 2006, 2009), Bertoni *et al.* (2011, 2013)

focused on design, works like those by Cook *et al.* (2006), Krucken and Meroni (2006) from the strategic focus, papers Lee *et al.* (2007), Chirumalla (2013), and Durugbo (2013) from the ICT focus area, Aurich *et al.* (2006) and Williams (2006) from the sustainability focus area.

This clear prevalence of the "design issue" is the clearest difference of this group with the others, where design was a side topic or it was not considered at all. Then we can conclude that the development/design of PSS contrasts with economic/social/environmental analysis. We can also suppose that behind these two tendencies, one toward design and the other one toward analyses, the presence of different viewpoints on PSS is quite evident, also on a time perspective: the first one (design) looks at the future and at what can be done; the second one (analyses) looks at the past and at what has already been done. This consideration can help us in identifying a promising future research need, linked to the aim of mixing and promoting the coexistence of these two tendencies, especially if we consider the potential benefits of implementing the analyses results into designs of future PSS.

An important aspect that received little attention is the nature of PSS as a socio-technical system, as mentioned in the introduction. Roy (2000) first acknowledged this characteristic of PSS, stating that it could provide essential end-use functions, resulting in better environmental and consumption performance rather than traditional products sold. After this work, scholars from design fields mainly focused on design methodologies and/or tools, and the concept of PSS as a socio-technical system has been reconsidered in recent years (Ceschin, 2014; Rivas-Hermann et al., 2015).

In particular, Ceschin (2014) starts from the premise that there is a need for a deep redefinition of consumption and production habits to ensure a successful adoption of sustainable PSS, acknowledging that PSS does not simply constitute a new offering, but can be viewed as a social innovation and a large-scale socio-technical change.

This radical change must involve the identification of the most appropriate "strategies and pathways to favour and hasten the introduction and scaling-up" of sustainable PSSs. That is why the author recognized that "the introduction of radical innovations requires the creation of partially protected socio-technical experiments. […] Protection allows incubation and maturation of radical socio-technical configurations by partly shielding them from the mainstream market selection environment." (p. 2)

We also performed a quantitative analysis among the groups of the conceptual structure. Moving from main topics retrieved among papers of the groups, our intent was to perform a correlation analysis, using as a base data showed in Table 7.

Table 7 – Main topics among the groups of conceptual structure

Topics	Economists	Environmentalists	All-Around	Designers
PSS model	8	6	2	47
Categories of PSS	4	2	1	15
Characteristics of PSS	15	14	3	96
PSS development/design	11	8	1	105
Applications of PSS	12	20	7	103
Benefits	3	5	1	32
Barriers	1	3	2	31
Drivers	1	2	2	19

Economists, Environmentalists and Designers show high correlations between them (more than 0.8). All-Around group is weakly correlated with Economists and Designers, while it has a strong correlation with Environmentalists. What these two groups have in common is the presence of a social/environmental analysis, and the most developed topic in the groups is that of "Applications": this evidence supports what was hypothesized above, that in literature the analysis of the social/environmental impact usually privileges a pragmatic/empirical approach.

As previously stated, the Economists group is the group with the highest number of papers dealing with "Characteristics of PSS", letting us conclude that the economic analysis usually privileges a theoretical/conceptual approach, without, however, predominating on the empirical purpose, considering that also "Applications" shows a considerable value.

We also observed that weak correlations showed by Economists and Designers with the All-Around group are probably due to the fact that "Characteristics" and "PSS development/design" (main topics among Economists and Designers) shows a low value in the third group, in which the only topic with a considerable value is "Application". This brought us to conclude that the analysis of both economic and environmental/social aspects should necessarily imply a pragmatic/empirical approach, excluding any insight on PSS design and development.

7 Future research directions

During the review, we charted future directions (when indicated in the papers). We then grouped them by categories of similarity and by year, in order to find out if there were some topics showing a trend through years. We did the same work also with future methodologies needed.

Table 8 – Future research directions divided by main focus areas

	Time period	1999 -	2005 -	2010 -	2013 -
Research directions	Economic dimension	1	2	12	22
	Environmental/Social dimension	4	6	7	13
	Strategy, competitiveness and general performance	5	7	16	25

	PSS design and implementation	4	10	10	18
	Relationships and networks	2	5	8	10
	Markets and customers	1	3	4	3
	Organization	1	1	2	4
	Technology	0	0	4	0
	Policy and regulation	0	0	1	4

Table 9 – Future research directions, methodologies

	Time period	1999 -	2005 -	2010 -	2013 -
Methodology	Conceptual study	0	1	3	2
	Literature review	0	0	0	2
	Case study	1	4	13	13
	Action research	0	4	3	7
	Survey	0	2	4	6

The topics “Environmental/Social dimension” and “PSS design and implementation” have been recognized as future research directions by almost the same number of papers over years, showing a little rise from the first to the second period, although the second one received more citations: this shows that these topics covered, and still cover, an important role in the development of the research about PSS.

Accordingly with the table listing main topics, “strategy, competitiveness and performance” is the most reported future direction, recognized as an important current and future research stream, incorporating the research streams about business models and collaborative consumption. But another important result emerging is that the economic dimension and evaluation of PSS, which was treated by very few authors (16%), has been recognized as a future direction by a rising number of papers over the years, confirming the need to deepen this aspect in future research.

Together with these relevant topics, we can see how “Relationships and networks” is an interesting emerging sub-field of research, followed by “Markets and customer” which shows a little interest in consumers’ perception of PSS, with a close eye on the Business-to-Consumer market: indeed, until today research about PSS has been mainly focused on the Business-to-Business market. Other topics like “Organization”, “Technology” and “Policy and regulation” show a low level of clear interest.

From the analysis of future methodologies, it emerges that, although there is already a high number of case studies in the literature, this methodology is recognized as still important from the development of the research field, particularly in the form of cross-case and cross-sector analysis, together with action research methodology. This can help in understanding how the research about PSS is still in a phase characterized by exploratory studies. Moreover, the (relatively) considerable

number of papers indicating survey as a needed methodology help understand that there is a need to start theory testing on what has so far emerged about PSS.

Moving from considerations above, we identified as main future research directions two potential fields:

- *Business models*: Reim *et al.* (2015) recognized the three categories of PSS (product-, use-, and result-oriented) as business models that can be implemented by organizations, also indicating as further development a deeper analysis of their characteristics and of tactics associated to each one.
- *Collaborative consumption*: Firnkorn and Müller (2011, 2012) investigated the potential of the car sharing system, which is one of the best examples in implementing use-oriented PSS, but there is still a lack of studies about the interconnection between the economic and cultural model of *collaborative consumption* and use-oriented PSS potential.

The directions outlined are even more significant if considered in relation to one of PSS's main concerns, which is (environmental) sustainability. Since the first publications, PSS has been labelled as an environmentally-friendly business model (Mont *et al.*, 2002; Tukker, 2004), mixing together the two main themes of sustainability and business models. This correlation, representing PSS's ability to address both environmental and economic sustainability, lasted until authors started questioning if PSS was capable of actually delivering the expected benefits, mainly for what concerns the environmental aspects (Tukker and Tischner, 2006). This lack of trust in PSS's environmental friendliness resulted in a clear separation of the two above-mentioned research streams, with papers focused on sustainability dealing with analyses of environmental/social impact, and papers focused on strategy and business models almost completely ignoring these aspects. In recent years some papers reconsidered the interrelation between these two aspects/streams of research (Xing *et al.*, 2013b; Centenera and Hasan, 2014): thanks to technological progress there has been an increase in new business models giving new importance to the sustainability impact, like *collaborative consumption* and *circular economy*, as already stated in the introduction of this work. These two topics represent what can be defined as a reprise or rather, an evolution of PSS's original concern in addressing all aspects of sustainability (environmental, economic, social). Centenera and Hasan (2014) conducted a research project that, although limited to the Australian context, "aims at developing a sustainable product-service system, a system incorporating financial, social, and environmental sustainability" (p. 62). The study involved all three categories of PSS, investigating for example reuse and recycle in the case of product-oriented PSS (which can be considered the main elements behind *circular economy* concept), and *collaborative consumption* and sharing models in the case of use-oriented PSS. Indeed this example shows a renewed interest in business models and

sustainability, as evidenced also by other recent works (Emili *et al.*, 2016; Firnkorn and Shaheen, 2016; Pereira *et al.*, 2016)

Furthermore, from the analysis of main topics (Table 5), we found a very small number of publications dealing with the topic of *economic analysis of PSS* and with *social/environmental analysis*.

Considering what emerged from the conceptual structure and from the analysis performed, these two topics can be further detailed in four specific research directions, each one considering some issues emerging from the four groups identified:

- There is a clear need for more works focusing on the economic analysis of PSS, mainly employing an empirical approach: useful contributions to the literature would be a longitudinal case study on the economic impact of PSS and/or a multi-sector study, in order to discover differences and similarities between results produced by PSS in different industries.
- Nowadays environmental analyses mainly employ qualitative and descriptive methodologies: there is a need for new quantitative methodologies, capable of describing and evaluating also indirect effects on social and environmental dimension attributable to PSS.
- This review has highlighted that there is a really low number of papers providing an analysis capable of covering all the three aspects of sustainability: following the methodology proposed in 1999 by Goedkoop *et al.* there is a clear need for new innovative analysis covering all the three aspects of PSS sustainability potential.
- Finally, although some papers already employ results of economic/social/environmental analyses in the design processes, future work should focus more on the opportunities offered by this integration.

8 Concluding remarks

The aim of our research was to identify, present, and summarize literature about PSS, in order to give a clear overview on this topic that is attracting more and more interest from scholars and practitioners. The interest in PSS, and in servitization in general, started in 1988 with the work by Vandermerwe and Rada, until in 1999 the term “PSS” appeared for the first time in the report by Goedkoop *et al.* After this publication, the topic attracted increasingly more interest over the years, also thanks to the contributions made by some important authors like Mont (2002, 2004), Manzini and Vezzoli (2001, 2003), Tukker (2004), who posed its theoretical bases.

Despite the lack of a unique and well-accepted definition, nowadays almost all authors seem to agree in recognizing the PSS as a business model, although this necessitates a deeper theoretical insight.

Literature mainly agrees about PSS benefits, barriers, and partly also on drivers, but from the descriptive and thematic analysis what emerged is a lack of clarity about PSS and its main fields: it started as a topic closely connected with sustainability, but subsequently different fields have developed other terminologies and focuses of research, developing their own theoretical base and frameworks. Therefore, we have found a lack of interconnection among fields and subject areas. For example, marketing uses the terms functional sale and hybrid solution to refer to PSS and few works cite works on engineering.

PSS design is one of the most attractive areas in literature, but in our opinion it cannot be considered as a research stream per se, because the number of papers focusing exclusively on design is very limited: the great majority of contributions always considers this aspect of PSS in relation to another major topic.

What emerged from the methodological structure (Section 4) and from main topics retrieved in literature (Section 5.2) is that literature has been and still is, mostly focused on the description and analysis, through case studies, of real implementation cases: the analyses has been mainly concerned with characteristics of PSS and/or tools, methods, and guidelines to support PSS development/design. We have showed that currently there are few studies analysing one or more aspects of sustainability (i.e. economic, environmental, social); this disproportion among topics emerges also from the conceptual structure proposed in Section 6. We have addressed this issue in the future directions proposed, which also point out the need to employ different methodologies, like longitudinal case studies and cross-sector case studies.

The added value of this review is in the structures proposed, which highlight interesting issues among PSS research domains, while providing a complete overview of literature from a different perspective, not employed in previous analyses; furthermore this contribution points out the past and emerging research fields coming from all the different fields and subject areas.

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Appendix 1 – Set of 224 analysed papers

Author(s)	Year	Journal	Research purpose	Methodology
Vandermerwe S., Rada J.	1988	European Management Journal	Theory building	Conceptual study
Goedkoop et al.	1999	Report commissioned by Dutch ministries of Environment (VROM) and Economic Affairs (EZ)	Theory building	Case study
Wise R., Baumgartner P.	1999	Harvard Business Review	Theory building	Conceptual study
Roy R.	2000	Futures	Theory building	Conceptual study
Manzini et al.	2001	Journal of Design Research	Exploration	Conceptual study
Mathieu V.	2001	Journal of Business and Industrial Marketing	Theory building	Case study
Mont O.	2002	Journal of Cleaner Production	Theory building	Conceptual study
Morelli N. (a)	2002	Design Issues	Theory refinement	Conceptual study
Morelli N. (b)	2002	Design Studies	Exploration	Case study
Heiskanen E., Jalas M.	2003	Corporate Social Responsibility and Environmental Management	Exploration	Conceptual study
Manzini E., Vezzoli C.	2003	Journal of Cleaner Production	Theory building	Case study
Maxwell D., van der Vorst R.	2003	Journal of Cleaner Production	Theory building	Case study
Mont O., Lindqvist T.	2003	Journal of Cleaner Production	Exploration	Case study
Oliva R., Kallenberg R.	2003	International Journal of Service Industry Management	Theory building	Case study
Halme et al.	2004	Ecological Economics	Theory building	Conceptual study
Mont O.	2004	Ecological Economics	Theory building	Case study
Tukker A.	2004	Business Strategy and the Environment	Theory building	Conceptual study
Besch K.	2005	Journal of Cleaner Production	Exploration	Case study
Aurich et al.	2006	Journal of Cleaner Production	Theory building	Case study
Briceno T., Stagl S.	2006	Journal of Cleaner Production	Exploration	Survey Case study
Cook et al.	2006	Journal of Cleaner Production	Theory building	Case study
Halme et al.	2006	Journal of Cleaner Production	Theory building	Case study
Krucken L., Meroni A.	2006	Journal of Cleaner Production	Theory building	Case study
Maxwell et al.	2006	Journal of Cleaner Production	Theory building	Case study

Mont et al. (a)	2006	Journal of Industrial Ecology	Exploration	Case study
Mont et al. (b)	2006	Journal of Cleaner Production	Theory building	Case study
Morelli N.	2006	Journal of Cleaner Production	Theory building	Conceptual study
Tasaki et al.	2006	Journal of Cleaner Production	Exploration	Case study
Tukker A., Tischner U.	2006	Journal of Cleaner Production	Descriptive	Literature review
Williams A.	2006	Journal of Cleaner Production	Exploration	Conceptual study
Baines et al.	2007	Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture	Descriptive	Literature review
Evans et al.	2007	International Journal of Production Research	Exploration	Case study
Lee et al.	2007	International Journal of Services Operations and Informatics	Theory building	Case study
Williams A.	2007	Journal of Cleaner Production	Theory refinement	Case study
Becker et al.	2008	Information Systems and e-Business Management	Theory building	Conceptual study
Devisscher T., Mont O.	2008	International Journal of Innovation and Sustainable Development	Exploration	Case study
Kang M.Y., Wimmer R.	2008	Journal of Cleaner Production	Descriptive	Conceptual study
Aurich et al.	2009	Journal of Manufacturing Technology Management	Theory refinement	Conceptual study
Azarenko et al.	2009	Journal of Manufacturing Technology Management	Theory building	Case study
Baxter et al.	2009	International Journal of Computer Integrated Manufacturing	Theory building	Case study
Bianchi et al.	2009	International Journal of Mathematics and Computers in Simulation	Exploration	Conceptual study
Isaksson et al.	2009	Journal of Engineering Design	Exploration	Case study
Jiang P., Fu Y.	2009	International Journal of Internet Manufacturing and Services	Theory building	Case study
Kimita et al.	2009	Journal of Manufacturing Technology Management	Theory building	Conceptual study
Maussang et al.	2009	Journal of Engineering Design	Theory refinement	Case study
Morelli N.	2009	Journal of Manufacturing Technology Management	Theory building	Conceptual study
Neely A.	2009	Operations Management Research	Theory testing	Survey
Pawar et al.	2009	International Journal of Operations & Production Management	Theory building	Conceptual study Case study
Rese et al. (a)	2009	Journal of Manufacturing Technology Management	Theory building	Conceptual study
Rese et al. (b)	2009	CIRP Journal of Manufacturing Science and Technology	Theory building	Case study

Rexfelt O., Hiort af Ornäs V.	2009	Journal of Manufacturing Technology Management	Theory building	Conceptual study
Roy R., Cheruvu K.S.	2009	International Journal of Internet Manufacturing and Services	Theory refinement	Conceptual study
Sakao et al.	2009	Journal of Manufacturing Technology Management	Descriptive	Literature review
Spring M., Araujo L.	2009	International Journal of Operations & Production Management	Theory building	Conceptual study
Sundin et al.	2009	Journal of Manufacturing Technology Management	Exploration	Case study
Tonelli et al.	2009	WSEAS Transactions on Business and Economics	Theory building	Action research

Yang et al.	2009	Computers & Industrial Engineering	Theory building	Conceptual study
Abramovici et al.	2010	Strojniški vestnik (Journal of Mechanical Engineering)	Theory building	Case study
Aurich et al.	2010	CIRP Journal of Manufacturing Science and Technology	Theory refinement	Conceptual study
Ceschin F., Vezzoli C.	2010	International Journal of Automotive Technology and Management	Exploration	Conceptual study
Durugbo et al.	2010	International Journal of Services Operations and Informatics	Theory building	Case study
Geng et al.	2010	Computers & Industrial Engineering	Theory building	Case study
Gottberg et al.	2010	Waste Management & Research	Exploration	Case study
Zhu et al.	2010	International Journal of Internet Manufacturing and Services	Theory building	Conceptual study
Johansson et al.	2010	Project Management Journal	Theory building	Case study
Kuo et al.	2010	International Journal of Advanced Manufacturing Technology	Theory building	Conceptual study
Lin et al.	2010	African Journal of Business Management	Theory building	Conceptual study
Martinez et al.	2010	Journal of Manufacturing Technology Management	Exploration	Case study
Meier et al. (a)	2010	CIRP Annals - Manufacturing Technology	Theory building	Conceptual study
Meier et al. (b)	2010	CIRP Journal of Manufacturing Science and Technology	Theory building	Conceptual study
Richter et al.	2010	CIRP Journal of Manufacturing Science and Technology	Theory building	Conceptual study
Roerich J.K., Lewis M.A.	2010	Construction Management and Economics	Theory building	Conceptual study
Schweitzer E., Aurich J.C.	2010	CIRP Journal of Manufacturing Science and Technology	Theory building	Case study
Sundin et al.	2010	CIRP Journal of Manufacturing Science and Technology	Exploration	Case study
Tan et al.	2010	CIRP Journal of Manufacturing Science and Technology	Theory refinement	Case study
Zhang Z., Chu X.	2010	International Journal of Computer Integrated Manufacturing	Theory building	Case study
Berkovich M., Leimeister J.M.	2011	Business & Information Systems Engineering	Exploration	Literature review
Bertoni A., Bertoni M.	2011	Design Principles and Practices	Theory building	Case study
Bertoni M., Larsson A.	2011	International Journal of Product Development	Exploration	Case study
Datta P.P., Roy R.	2011	International Journal of Operations & Production Management	Theory building	Conceptual study
De Coster R.	2011	International Journal of Advanced Manufacturing Technology	Theory building	Case study
Durugbo et al.	2011	International Journal of Advanced Manufacturing Technology	Exploration	Case study

Erkoyuncu et al.	2011	International Journal of Advanced Manufacturing Technology	Exploration	Conceptual study
Firnkorn J., Müller M.	2011	Ecological Economics	Theory testing	Survey
Gao et al.	2011	Journal of Intelligent Manufacturing	Exploration	Conceptual study
Geng et al.	2011	Expert Systems with Applications	Theory building	Case study
Geum et al. (a)	2011	Journal of Engineering and Technology Management	Theory building	Case study
Geum et al. (b)	2011	Service Business	Theory building	Case study
Geum Y., Park Y.	2011	Journal of Cleaner Production	Theory building	Conceptual study
Huang et al.	2011	International Journal of Advanced Manufacturing Technology	Theory building	Case study
Kuo T.C.	2011	International Journal of Advanced Manufacturing Technology	Theory building	Case study
Lelah et al.	2011	Journal of Cleaner Production	Theory building	Case study
Lockett et al.	2011	Journal of Manufacturing Technology Management	Exploration	Case study
Mittermeyer et al.	2011	International Journal of Advanced Manufacturing Technology	Exploration	Case study
Velamuri et al.	2011	Journal fur Betriebswirtschaft (Management Review Quarterly)	Descriptive	Literature review
Wang et al.	2011	International Journal of Production Research	Theory building	Conceptual study
Zhu et al.	2011	International Journal of Advanced Manufacturing Technology	Theory building	Conceptual study
Akasaka et al.	2012	Computers in Industry	Theory building	Case study
Alix T., Zacharewicz G.	2012	Computers in Industry	Theory building	Case study
Allen Hu et al.	2012	International Journal of Environmental Science and Technology	Theory building	Conceptual study
Bandinelli R., Gamberi V.	2012	Journal of Manufacturing Technology Management	Exploration	Case study
Bankole et al.	2012	International Journal of Computer Integrated Manufacturing	Theory refinement	Literature review
Catulli M.	2012	Journal of Manufacturing Technology Management	Theory refinement	Case study
Cavalieri S., Pezzotta G.	2012	Computers in Industry	Theory refinement	Literature review
Clayton et al.	2012	Journal of Manufacturing Technology Management	Exploration	Case study
Cook et al.	2012	Journal of Cleaner Production	Exploration	Case study
Dongmin et al.	2012	Computers in Industry	Theory building	Case study
Ericson A., Wenngren, J.	2012	The International Journal of Technology, Knowledge, and Society	Exploration	Conceptual study

Firnkorn J., Müller M.	2012	Business Strategy and the Environment	Exploration	Case study
Garetti et al.	2012	Computers in Industry	Theory refinement	Conceptual study
Geng et al.	2012	International Journal of Advanced Manufacturing Technology	Theory building	Case study
Geng X., Chu X.	2012	Expert Systems with Applications	Theory building	Case study
Harrington T.S., Srai J.S.	2012	International Journal of Product Development	Theory building	Case study
Hussain et al.	2012	Computers in Industry	Theory building	Case study
Kim S., Yoon B.	2012	Service Business	Theory building	Conceptual study
Komoto et al.	2012	CIRP Annals - Manufacturing Technology	Theory building	Case study
Kuo T.C., Wang M.L.	2012	International Journal of Production Research	Theory building	Case study
Lee et al. (a)	2012	Journal of Cleaner Production	Theory building	Case study
Lee et al. (b)	2012	International Information Institute	Theory building	Conceptual study
Li et al.	2012	Computers in Industry	Theory building	Case study
Lim et al.	2012	Journal of Cleaner Production	Theory building	Conceptual study
Minguez et al.	2012	CIRP Journal of Manufacturing Science and Technology	Theory building	Conceptual study
Mo J.P.T.	2012	Advances in Decision Science	Theory building	Case study
Nishino et al.	2012	CIRP Annals - Manufacturing Technology	Theory building	Conceptual study
Pardo et al.	2012	Sustainability	Theory building	Case study
Pezzotta et al.	2012	CIRP Journal of Manufacturing Science and Technology	Exploration	Case study
Phumbua S., Tjahjono B.	2012	International Journal of Production Research	Theory refinement	Literature review
Sakao T., Lindahl M.	2012	CIRP Annals - Manufacturing Technology	Theory building	Case study
Sun et al.	2012	International Journal of Computer Integrated Manufacturing	Theory building	Case study
Vasantha et al.	2012	Journal of Engineering Design	Theory refinement	Literature review
Wagner et al.	2012	International Journal of Technology Intelligence and Planning	Theory refinement	Literature review
Yoon et al.	2012	Expert Systems with Applications	Theory building	Case study
Zhu et al.	2012	Computers in Industry	Theory building	Case study

Barquet et al.	2013	Industrial Marketing Management	Theory building	Case study
Belvedere et al.	2013	International Journal of Production Research	Theory testing	Survey
Bertoni A.	2013	Design Studies	Exploration	Case study
Bertoni et al.	2013	Journal of Cleaner Production	Theory building	Action research
Beuren et al.	2013	Journal of Cleaner Production	Descriptive	Literature review
Boehm M., Thomas O.	2013	Journal of Cleaner Production	Theory refinement	Literature review
Cao W., Jiang P.	2013	International Journal of Production Research	Theory building	Case study
Carreira et al.	2013	Journal of Engineering Design	Theory refinement	Action research
Ceschin F.	2013	Journal of Cleaner Production	Exploration	Case study
Chirumalla et al.	2013	International Journal of Technology Intelligence and Planning	Theory building	Case study
Chirumalla K.	2013	Research Technology Management	Exploration	Case study
Colen P.J., Lambrecht M.R.	2013	The Service Industries Journal	Theory building	Case study
Dewberry et al.	2013	The Design Journal	Descriptive	Case study
Dimache A., Roche T.	2013	International Journal of Operations & Production Management	Theory building	Action research
Durugbo C. (a)	2013	International Journal of Production Research	Exploration	Case study
Durugbo C. (b)	2013	Systems Engineering	Exploration	Case study
Durugbo C., Riedel J.C.K.H.	2013	International Journal of Production Research	Theory building	Conceptual study
Friebe et al.	2013	Energy Policy	Exploration	Survey
Kastalli et al.	2013	California Management Review	Theory refinement	Case study
Kuo T.C.	2013	Journal of Intelligent Manufacturing	Theory building	Case study
Laperche B., Picard F.	2013	Journal of Cleaner Production	Theory refinement	Case study
Li N., Jiang Z.	2013	Computers & Operations Research	Theory refinement	Conceptual study
Long et al.	2013	International Journal of Production Research	Theory building	Conceptual study
Sakao et al.	2013	Journal of Systems Science and Systems Engineering	Theory building	Case study
Shimomura et al.	2013	CIRP Annals - Manufacturing Technology	Theory building	Case study
Song et al.	2013	International Journal of Production Research	Theory building	Case study
Teixeira et al.	2013	Journal of Manufacturing Technology Management	Exploration	Conceptual study
Tu et al. (a)	2013	Mathematical Problems in Engineering	Exploration	Survey
Tu et al. (b)	2013	Journal of Industrial and Production Engineering	Theory building	Case study

Van Ostaeyen et al.	2013	Journal of Cleaner Production	Theory building	Conceptual study
Velamuri et al.	2013	International Journal of Innovation Management	Exploration	Case study
Wagner et al.	2013	International Journal of Industrial Engineering and Management	Theory building	Conceptual study
Wang et al.	2013	International Journal of Production Research	Theory building	Conceptual study
Wang X., Durugbo C.	2013	Expert Systems with Applications	Theory building	Case study
Xing et al. (a)	2013	Journal of Cleaner Production	Theory building	Case study
Xing et al. (b)	2013	International Journal of Production Research	Theory building	Case study
Alfian et al.	2014	Computers & Industrial Engineering	Theory building	Case study
Amaya et al.	2014	Journal of Engineering Design	Theory building	Case study
Berkovich et al.	2014	Requirements Engineering	Theory building	Case study
Centenera J., Hasan M.	2014	International Business Research	Exploration	Case study
Ceschin F.	2014	International Journal of Design	Theory Building	Action research
Cook M.	2014	Environmental Innovation and Societal Transitions	Exploration	Conceptual study
Durugbo C.	2014	International Journal of Production Research	Theory building	Case study
Gaiardelli et al.	2014	Journal of Cleaner Production	Theory building	Case study
Holmbolm et al.	2014	Journal of Manufacturing Technology Management	Descriptive	Literature review
Kreye et al.	2014	Production Planning & Control	Theory building	Case study
Lindahl et al.	2014	Journal of Cleaner Production	Theory building	Case study
Liu et al.	2014	International Journal of Physical Distribution & Logistics Management	Theory building	Conceptual study
McKay A., Kundu S.	2014	Advanced Engineering Informatics	Theory building	Conceptual study
Parida et al.	2014	Research Technology Management	Exploration	Survey Case study
Rivas-Hermann et al.	2014	Journal of Cleaner Production	Theory refinement	Case study
Schotman H., Ludden G.D.S.	2014	Journal of Design Research	Exploration	Case study
Settanni et al.	2014	International Journal of Production Economics	Theory building	Case study
Shokohyar et al.	2014	Journal of Intelligent Manufacturing	Theory building	Case study

Smith et al.	2014	International Journal of Operations & Production Management	Exploration	Case study
Turunen T., Finne M.	2014	European Management Journal	Theory building	Conceptual study
Wu X., Ryan S.M.	2014	The Engineering Economist	Theory building	Conceptual study
Xie et al.	2014	International Journal of Production Research	Theory building	Conceptual study
Armstrong et al.	2015	Journal of Cleaner Production	Exploration	Case study
Cherubini et al.	2015	Journal of Cleaner Production	Exploration	Case study

Chou et al.	2015	Journal of Cleaner Production	Theory building	Conceptual study
Gelbmann U., Hammerl B.	2015	Journal of Cleaner Production	Theory refinement	Case study
Hannon et al.	2015	Journal of Cleaner Production	Theory building	Case study
Igba et al.	2015	Robotics and Computer-Integrated Manufacturing	Theory building	Case study
Joore, P., Brezet, H.	2015	Journal of Cleaner Production	Descriptive	Conceptual study
Liedtke et al.	2015	Journal of Cleaner Production	Exploration	Action research
Mylan J.	2015	Journal of Cleaner Production	Theory refinement	Case study
Overholm A.	2015	Journal of Cleaner Production	Theory building	Case study
Park H., Yoon J.	2015	Service Business	Theory building	Case study
Pezzotta et al.	2015	Mechatronics	Theory building	Case study
Piscicelli et al.	2015	Journal of Cleaner Production	Theory refinement	Case study
Plepys et al.	2015	Journal of Cleaner Production	Descriptive	Literature review
Reim et al.	2015	Journal of Cleaner Production	Theory refinement	Literature review
Salazar et al.	2015	Journal of Cleaner Production	Exploration	Case study
Tukker A.	2015	Journal of Cleaner Production	Descriptive	Literature review
Yip et al.	2015	Technology in Society	Theory building	Case study
Zhang et al.	2015	Journal of Cleaner Production	Exploration	Case study
Armstrong et al.	2016	Sustainable Development	Exploration	Case study
De Senzi Zancul et al.	2016	Business Process Management Journal	Theory Building	Case study
Elnadi M., Shehab E.	2016	Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture	Theory Building	Case study
Emili et al.	2016	Energy for Sustainable Development	Theory Building	Case study
Firnkorn J., Shaheen S.	2016	Journal of Cleaner Production	Theory Refinement	Conceptual study
Hobson, K.	2016	Progress in Human Geography	Descriptive	Conceptual study
Kjaer et al.	2016	Journal of Cleaner Production	Exploration	Literature review
Mahlamäki et al.	2016	International Journal of Condition Monitoring and Diagnostic Engineering Management	Exploration	Case study
Parry et al.	2016	Foresight and STI Governance	Descriptive	Survey

Pereira et al.	2016	Journal of Cleaner Production	Theory Building	Case study
Qu et al.	2016	Computers in Industry	Descriptive	Literature review
Reim et al.	2016	International Journal of Operations & Production Management	Exploration	Case study
Santamaria et al.	2016	Journal of Cleaner Production	Theory Building	Conceptual study
Tran T., Park J.Y.	2016	Sustainability	Theory Building	Case study