A Conceptual Model to Support Sustainable Product-Service System Implementation in the Brazilian Agricultural Machinery Industry

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Abstract

Many studies demonstrate the potential contribution of the Product-Service System (PSS) to the development of sustainable management practices and Circular Economy (CE). However, companies face challenges when implementing PSS, and few studies examine how the manufacturing industry can develop sustainable offerings by adopting product-oriented PSS, especially in the agricultural machinery industry. Thus, we investigated how this industry perceives environmental sustainability and product-oriented PSS, and we identified practices that can be implemented to qualify the life cycle management of their products. Based on that, we proposed a conceptual model for implementing product-oriented PSS in the agricultural machinery sector. An exploratory research was carried out in two steps: a systematic literature review complemented by multiple case studies. We list the possibilities of product-oriented PSS services that can be offered for traditional industries to guide their business towards sustainable practices. In parallel, we have identified good practices and benefits of adopting product-oriented PSS. Subsequently, we conducted a diagnosis on sustainability and product-oriented PSS in agricultural machinery companies. Although companies already offer some services to customers, our results show ample opportunities for improvement, especially to offer product-oriented PSS considering socio-environmental issues. In this sense, the conceptual model proposed allows industries to expand their understanding and adherence to product-oriented PSS. As contributions, we demonstrate how the agricultural machinery industry can develop sustainable practices and promote CE through product-oriented PSS implementation.

Keywords: Product-Service System; Servitization; Circular Economy; Sustainability; Agricultural Machinery.

1. Introduction

The potential contribution of the Product-Service System (PSS) to the development of sustainable management practices is discussed in many studies (Annarelli et al., 2020; Hao et al., 2021; Rosa et al., 2019a). PSS is a business model that integrates products and services

designed to meet customer needs sustainably, reducing resource consumption and environmental impacts (Annarelli et al., 2016; Munten et al., 2021). It is considered a strategy for Circular Economy (CE) (Guzzo et al., 2019; Halstenberg and Stark, 2019; Kaddoura et al., 2019; Pieroni et al., 2019).

Theoretically, three categories of PSS can be distinguished: (i) product-oriented PSS, (ii) use-oriented PSS, and (iii) result-oriented PSS (Tukker, 2004). In this article, we focus on product-oriented PSS for some reasons. First, it is challenging to shift customers' habits in some contexts since many customers attach much more value to the ownership of the products they use (Annarelli et al., 2016; Tukker, 2015). Second, some companies are not interested in changing their business model from selling products to selling services (Alghisi and Saccani, 2015; Zine et al., 2016), mainly because it requires an entirely different organization and skill set than in the case of product sales (Alghisi and Saccani, 2015; Tukker, 2015). Thus, the lower complexity of product-oriented PSS for implementing strategies related to the CE may lead to a higher adoption rate by organizations (Kaddoura et al., 2019).

The services offered in product-oriented PSS help keep the products in use for a longer period, extending their useful life (Kjaer et al., 2019; Yang et al., 2018). The extension of the life cycle promotes a slowdown in the flow of materials, less waste generation (Arabi et al., 2018), and a reduction in the emission of pollutants in the atmosphere (Zhao et al., 2019). However, although professionals and researchers recognize the role of product-oriented PSS in the practice of sustainable product management (Kaddoura et al., 2019; Sassanelli et al., 2020) and sustainable consumption and production processes (Munten et al., 2021), its adoption by organizations is still restricted (Cavalieri et al., 2020; de Jesus Pacheco et al., 2019). Many companies face challenges when implementing PSS due to the internal inability to design and implement offers appropriately (Pezzotta et al., 2018; Rosa et al., 2019b).

Furthermore, PSS studies are mostly incorporated into the engineering and business literature and less developed in the environmental literature (Doni et al., 2019; Tukker, 2015). There is a need in expanding knowledge regarding the environmental and social aspects of PSS (Annarelli et al., 2016; Kristensen and Remmen, 2019; Suh, 2019) and advance the role of the PSS in the transition to a sustainable CE (Díaz-Garrido et al., 2018; Kristensen and Remmen, 2019). Considering this and the lack of knowledge regarding methods for developing PSS solutions respecting CE aspects (Fernandes et al., 2020), there are opportunities for studies that examine how the manufacturing industry can develop more sustainable offerings through the adoption of product-oriented PSS (Guzzo et al., 2019).

In addition to that, a research opportunity refers to how "traditional" industries can become

providers of products and services (Baines et al., 2009; Reim et al., 2015) since ideas about how industries implement and manage the PSS are still limited (Cavalieri et al., 2020). Moreover, although research on product-oriented PSS has been extended concerning the manufacturing industry (Calabrese et al., 2018), studies dedicated to the agricultural machinery sector have not received much attention (Corti et al., 2015).

When agricultural machinery is used intensively, and without monitoring, its emissions can be comparable to road vehicles (Waheed et al., 2020). However, most of the studies focus on the car segment and in the context of developed economies (Pallaro et al., 2017). In addition, there is a need to consider sustainable aspects at all stages of the life cycle of agricultural machinery (Banerjee and Punekar, 2020). Therefore, a latent demand to expand sustainable practices in the field involves implementing actions to manage and control the use of agricultural machinery and equipment (Gorjian et al., 2021; Waheed et al., 2020). Besides the qualification of processes and products based on environmental innovation carried out within the industry (da Silveira et al., 2021), it is also imperative to holistically manage the use and end-of-life of the products designed and marketed (Banerjee and Punekar, 2020; Pallaro et al., 2017).

Considering the above, we state the following research questions:

RQ1: How do the agricultural machinery and equipment industry perceive environmental sustainability and product-oriented PSS?

RQ2: What practices can be suggested so that the agricultural machinery and equipment industry can qualify the life cycle management of its products to contribute to CE?[1]

Based on these questions, we propose a conceptual model for implementing product-oriented PSS in the agricultural machinery sector. We justify the proposition of the conceptual model since many companies, mainly medium and small ones, need guidance and paths to adhere to and qualify their processes (de Jesus Pacheco et al., 2019; Hernández Pardo et al., 2012). Furthermore, the conceptual model enables companies to adjust suggested practices based on their competencies and resources (Annarelli et al., 2021).

To answer these questions, we conducted a systematic literature review followed by multiple case studies, as presented in Section 2. As theoretical advances, the research demonstrates how the agricultural machinery industry can contribute to sustainable management practices and CE through product-oriented PSS implementation. Furthermore, it enriches discussions about the potential of product-oriented PSS to increase the product life cycle and reduce waste

[1] In this study, "perception" refers to the ability to identify services, barriers, benefits, and good practices associated with developing Product-Oriented PSS". "Qualify" means to improve, to consider sustainable aspects in product life cycle management

generation. As practical advances, we highlight the proposed conceptual model, allowing industries to expand their understanding and adherence to product-oriented PSS practices. The research presents significant contributions to encouraging and helping agricultural machinery companies to develop sustainable production and consumption practices.

2. Materials and Methods

Considering the guiding questions, we conducted a two-step exploratory study. Exploratory research is recommended when researchers need an in-depth understanding of a problem to identify relevant courses of action (Hair et al., 2007). Following this direction, we initially developed a qualitative study through systematic research on secondary data (sub-section 2.1.) to clarify the concept of product-oriented PSS, list possibilities of services to be aggregated in traditional industries, and map good practices and benefits of its adoption. This step allowed us a detailed view of these points in studies carried out in the literature specific to product-oriented PSS, supporting RQ2. Afterward, we carried out a qualitative field research (sub-section 2.2.) through multiple case studies that made it possible to analyze the perceptions of the agricultural machinery and equipment companies about sustainability and product-oriented PSS. This step provided a comprehensive diagnosis of the agricultural machinery and equipment sector, supporting RQ1. Based on the results, we built a conceptual model for product-oriented PSS implementation.

2.1. Systematic Literature Review

Systematic reviews allow the synthesis of research contributions in determining fields (Tranfield et al., 2003). To guarantee the reliability and validity of the results, we conducted the systematic literature review following four steps, developed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) (Moher et al., 2009), as shown in Figure 1.

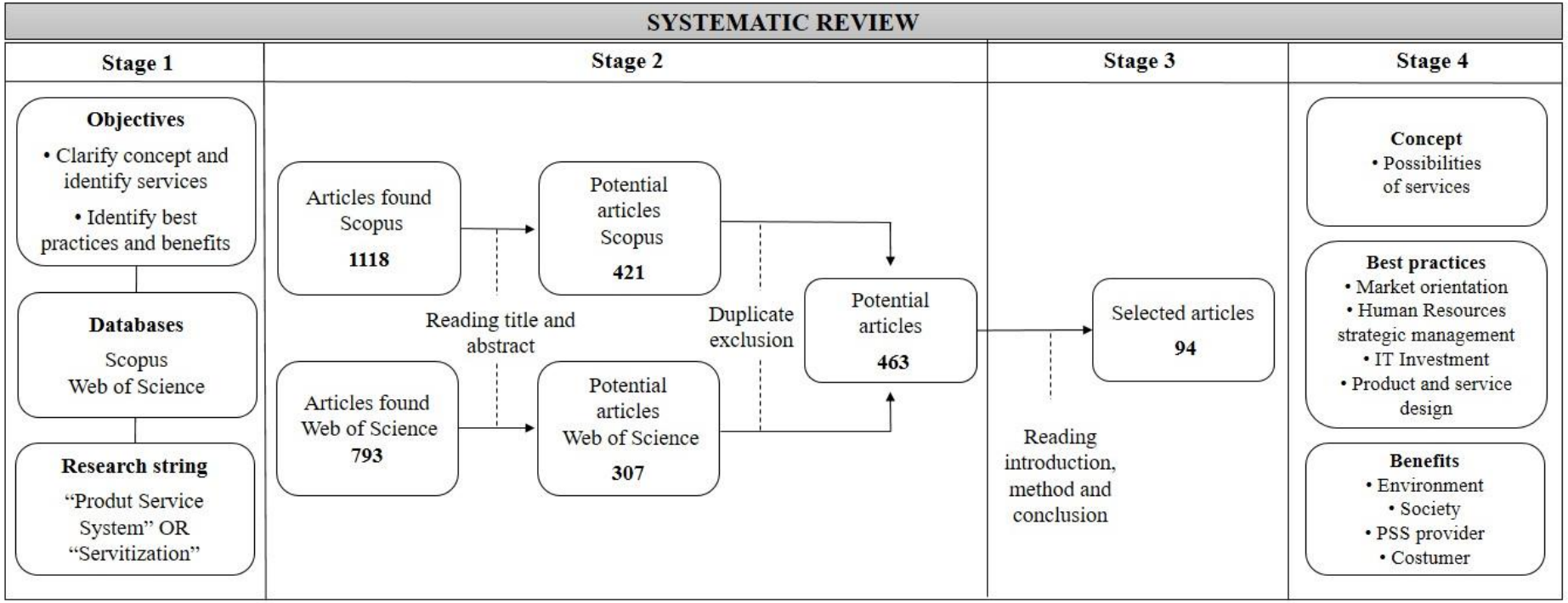

Figure 1 - Steps of the systematic literature review (source: authors' elaboration based on Moher et al., 2009).

Stage 1 consisted of defining criteria for the protocol (i). We defined as main objectives to clarify the concept of product-oriented PSS and identify its benefits and good practices for its successful implementation. The search string used was "Product Service System" or "Servitization" in Scopus and Web of Science databases. Scopus is the largest database of abstracts and citations in the peer-reviewed literature, covering 70 million items and with more than 1.7 billion references cited (Elsevier, 2021). Web of Science contains more than 1.9 billion cited references, with more than 171 million records (Clarivate, 2021).

Stage 2 comprised the execution of the review through the search for the terms previously defined and the preliminary selection of the articles (ii). This phase was conducted in 2020. The following inclusion criteria were established in the mechanisms of the databases: only articles containing one of the defined keywords in the title, keywords, and abstract; only studies published in journals, and finally, only articles published in the English language. The year of publication was not used as a restriction. We decided to select only empirical articles to analyse further examples of the application of product-oriented PSS in companies and the benefits and good practices performed by them. By applying the inclusion and selection criteria in the search engines, 1,911 articles were obtained, including duplicate materials.

From reading the title and summary of the 1,911 articles, we excluded those that: dealt explicitly with the use-oriented or result-oriented PSS categories or disagreed with the objectives defined for this study. After excluding duplicates, 463 potential articles were selected and organized in an electronic spreadsheet. Considering that some articles did not specify in the summary which category of PSS was used, Stage 3 comprised the content evaluation of the selected articles (iii), involving the reading of the introduction, method, and conclusion sections of the articles, intending to exclude works that were not related to product-oriented PSS or theoretical review articles. Finally, 94 empirical articles were selected for data extraction and further analysis. Finally, Stage 4 of extraction and synthesis of the results proceeded (iv), a phase in which the contributions of the studies related to the research questions were identified and organized through a content analysis of the articles.

2.2. Field Research: Multiple Case Study

The stage of obtaining primary data was performed through multiple case studies, enabling a deeper understanding of a phenomenon in development or whose dimensions have not yet been fully understood (Yin, 2009). We defined the population of interest as medium and large Brazilian companies operating in the agricultural machinery and equipment segment. Brazil has essential characteristics that justify the selection of cases, mainly due to the relevance of the agricultural segment to the country's economic activity, which helps boost other sectors of

Brazilian industry (Abimaq, 2020; Simers, 2020). The agricultural machinery industry in Brazil is dominated mainly by local machinery manufacturers, and the country is the sixth-largest exporter of agricultural machinery (Chartuni Mantovani et al., 2019). Additionally, the country has favorable climatic conditions for agricultural production and an extension of potentially arable land (da Silveira et al., 2021; Zylbersztajn, 2010).

Considering that selecting the number of cases in multiple case projects must follow a logic of replication as the researcher needs for the study, and not sampling (Yin, 2009), we selected six companies to be investigated. These cases were selected based on the following criteria: (i) ease of access to companies, (ii) understanding of the participants on the topic investigated, and (iii) the economic importance of these companies to the region. Thus, we used a convenience-based sampling method (Etikan, 2016). Table 1 shows the characterization of the researched sample. To ensure greater reliability and robustness of the data, two subjects from each company were interviewed, one of them working in the Product Engineering area and the other in the Commercial area, totaling 12 interviews. Also, to increase the corpus of information, we triangulate the data by analyzing companies' information provided in public reports.

Unit (Company)	**Number of employees**	**Interviewee**	
		Role	**Assumed name**
Company 1: Manufacturer of planter, distributors, , agricultural sprayers, seeder, among others	1,200	Commercial Manager Project Analyst	Interviewee A Interviewee B
Company 2: Manufacturer of planter, tractors, combine harvester, agricultural sprayer amont others	1,300	Marketing Specialist Product Engineering Manager	Interviewee C Interviewee D
Company 3: Manufacturer of planter, seeder, distributors, agricultural sprayers, mowers, among others	450	Export and Import Coordinator Product Engineering Manager	Interviewee E Interviewee F
Company 4: Manufacturer of planter, seeder, distributors, spreaders, platforms, agricultural trailers, among others	2,500	Customer Service Center Coordinator Project Analyst	Interviewee G Interviewee H
Company 5: Manufacturer of planters, distributors, planers, among others	370	Sales Planning and Administration Manager Product Engineering Manager	Interviewee I Interviewee J
Company 6: Manufacturer of planters, centrifugal irrigation, shaver, among others	200	Commercial Manager Product Engineering Manager	Interviewee K Interviewee L

Table 1 - Characterization of companies and interviewee (source: authors' elaboration).

We developed the data collection instrument based on the content extracted from the literature review. Before its application, it was validated by specialists, two from the Production Engineering area and two from the Environmental Engineering area. The instrument consisted of open-ended questions to allow respondents to spontaneously elaborate their answers (the data collection instrument is available as Supplementary Material). Regarding the data collection procedure, the direct approach was used through in-depth interviews (Malhotra, 2019). After previous scheduling, the interviews were conducted through the Google Meet© platform, lasting between 45 and 75 minutes each. The interviews were recorded, with authorization, for later transcription and analysis.

We performed the data analysis throughout content analysis (Bardin, 1977). First, the recordings were transcribed in full, thus generating the corpus of analysis. Based on the propositions established by the author for the treatment of data in content analysis, the grouping method used considered a structure resulting from the theoretical and practical foundation of the authors, correlating classes of events and ordering them. To this, we adopted a deductive approach, in which the analytical categories were defined a priori (Table 2) according to the systematic literature review carried out (Nematollahi and Tajbakhsh, 2020).

Category	Subcategory
Barriers	Internal
	External
Benefits	Benefits to the environment
	Benefits to the community
	Benefits to the PSS provider
	Benefits to costumers
Good Practices	Market orientation
	Human Resources Strategic Management
	Information and Communication Technology Investment
	Sustainable product and service design

Table 2 - Category for content analysis (source: authors' elaboration).

3. Theoretical Background

This section describes the results of the systematic literature review. Initially, the concept and possibilities of product-oriented PSS are described (sub-section 3.1) and, subsequently, the good practices and benefits of adoption (sub-section 3.2).

3.1. Concept and Possibilities for Product-Oriented PSS

Product-oriented PSS corresponds to a company's product and service development process moving towards the servitization process (Bandinelli and Gamberi, 2011). Servitization is applied when companies, in addition to products, start offering services to their customers (Li et al., 2015). Its emphasis is on services related to the sale of a product, which is still the company's focus (Kim and Yoon, 2012; Reim et al., 2015; Rosa et al., 2019b). In the case of product-oriented PSS, tangible ownership is transferred to the customer, and some additional services are provided (Tenucci and Supino, 2019; Yang and Evans, 2019; Zhao et al., 2019).

The value proposition of this offer is related to a wide range of services that support the product during its period of use or other stages of the life cycle (Kjaer et al., 2018; Song and Sakao, 2017; Suh, 2019). Product-oriented PSS includes incorporating services such as installation, maintenance, repair, updates, remote monitoring, consulting, training, financial services, supply of spare parts, home delivery, documentation, customer support, warranty, inspection, and diagnosis. At the end of its useful life, services such as return, recycling, remanufacturing, and dismantling can also be offered. Considering that the CE can be achieved through maintenance, repair, reuse, remanufacturing, and recycling services (Geissdoerfer et al., 2017), different studies demonstrate the potential contribution of the product-oriented PSS to the development of circular models (Kaddoura et al., 2019; Khan et al., 2019; Pieroni et al., 2019).

Based on the analysis of the sampled articles, we established the guiding concept of the referred business model: "Product-oriented PSS can be understood as a marketable set of products and services, in which ownership of the product is transferred to the customer, and different services are offered throughout the product's life cycle to improve its functionality and durability, to be sustainable and generate value for customers.". Based on the content of the selected articles, as supplementary material, we present a set of possibilities for using product-oriented PSS.

3.2. Product-Oriented PSS: Good Practices and Benefits

To identify the good practices associated with product-oriented PSS, we identified a set of examples associated with antecedents such as market orientation, strategic people management, investment in information and communication technology, and sustainable product and services design (Table 3). As for the benefits of adoption, we see gains for the environment, community, PSS provider, and customers, as shown in Table 4.

Dimension	Factors	Authors
Market orientation	Collection of customer needs	Bandinelli and Gamberi (2011); Kim and Yoon (2012); Tran and Park (2014); Peruzzini et al. (2015); Zine et al. (2016); Ayala et al. (2017); Andriankaja et al. (2018); Dimitris Mourtzis et al. (2018a); Khan et al. (2019); H. Li, et al. (2019); Sayar and Er (2019); Zhao et al. (2019)
	Collection of customer feedback	Alghisi and Saccani (2015); Resta et al. (2015); Weeks and Benade (2015); Wan et al. (2018); Mourtzis et al. (2017); Dimitris Mourtzis et al. (2018c); Khan et al. (2019)
	Define the PSS requirements based on customers' needs	Alix and Zacharewicz (2012); Sutanto et al. (2015); Zine et al. (2016); Andriankaja (2018); Haber and Fargnoli (2019)
	Development of ways to protect against competition	Resta et al. (2015); Karlsson et al. (2018); Khan et al. (2019); Annarelli et al. (2020)
	An approach centered on customer satisfaction	Resta et al. (2015); Weeks and Benade (2015); Dimitris Mourtzis et al. (2018b)
	Customer support concerning the offer	Gelbmann and Hammerl (2015); Van der Laan and Aurisicchio (2019)
	Setting goals considering sustainable aspects	Manzini and Vezzoli (2003); Mourtzis et al. (2018b)
Human Resources Strategic Management	Using cross-functional teams	Bandinelli and Gamberi (2011); Giuditta Pezzotta et al. (2012); Visnjic Kastalli and Van Looy (2013); Belvedere et al. (2013); Laperche and Picard (2013); Gelbmann and Hammerl (2015); Parida et al. (2014); Tran and Park (2014); Alghisi and Saccani (2015); Rabetino et al. (2015); Resta et al. (2015); Grubic and Peppard (2016); Sheng et al. (2017); Szwejczewski et al. (2015); Zancul et al. (2016); Zine et al. (2016); Ayala et al. (2017); Song and Sakao (2017); Wan et al. (2017); Ayala et al. (2019); Kristens and Remmen (2019)
	Good training and development practices	Barquet et al. (2013); Parida et al. (2014); Alghisi and Saccani (2015); Resta et al.(2015); Szwejczewski et al. (2015); Weeks and Benade (2015); Zancul et al. (2016); Zine et al. (2016); Adam (2018); Sayar and Er (2019); Leoni (2019); Haber and Fargnoli (2019)
	Investment in human resources	Li, Hua et al. (2015); Laperche and Picard (2013); Leoni (2019)
	Costumer's education	Armstrong et al. (2015); Parida et al. (2014)
	Creating shared vocabulary among those involved	Laperche and Picard (2013); Karlsson et al. (2018)
	PSS potential recognition and team perseverance	Adam et al. (2017); Li, Hua et al. (2015)
	Identification of the resources and skills needed to offer PSS	Parida et al. (2014)
Information and Communication Technology Investment	Use of remote monitoring technologies, cyber-physical systems, internet of things	Belvedere et al. (2013); Peruzzini et al. (2015); Weeks and Benade (2015); Zancul et al. (2016); Grubic and Jennions (2018); Palmer et al. (2017); Wan et al. (2017); Grubic (2018); Kaňovská and Tomášková (2018); Maleki et al. (2018); Mourtzis et al. (2018); Raja et al. (2018); Sayar and Er (2018); Wan et al. (2018); Basirati et al. (2019); Chiu et al. (2015); Olivotti et al. (2019); Sayar and Er (2019)
	Historical data usage	Szwejczewski et al (2015); Grubic and Peppard (2016)
Sustainable product and service design	Establishing partnerships with external agents of the organization	Alghisi and Saccani (2015); Peruzzini et al. (2015); Weeks and Benade (2015); Ayala et al. (2017); Ayala et al. (2019); Pieroni et al. (2019)
	Performance indicators usage for PSS	Visnjic Kastalli and van Looy (2013); H. Li et al. (2014); Zine et al. (2016); Mourtzis et al.(2017); Leoni (2019); Sayar and Er (2019)

	Development of products that facilitate the performance of services	Maxwell and Van Der Vorst (2003); Szwejczewski et al. (2015); Kuo et al. (2019)
	Development of ways to demonstrate confidence and tangibility to the offer	Armstrong et al. (2015); Sharma and Kumar (2016)
	Parallel product and service development	Resta et al. (2015); Zine et al. (2016); Sayar and Er (2019)
	Using best practices from other companies	Alghisi and Saccani (2015); Wan et al. (2019)

Table 3 - Good practices for implementing product-oriented PSS (source: authors' elaboration).

Dimension	Variables	Authors
Benefits to the environment	Extending the product's useful life	Manzini and Vezzoli (2003); Maxwell and Van der Vorst (2003); Gao et al. (2011); Hernández Pardo et al. (2012); Armstrong et al. (2015); Gelbmann and Hammerl (2015); Shokohyar et al. (2014); Arabi et al. (2018); Corvellec and Stål (2017); Kjaer et al. (2019, 2018); Mourtzis et al. (2018c); Wirawan et al. (2018); Yang et al. (2018); Kaddoura et al. (2019); Khan et al. (2019); Kristensen and Remmen (2019); Kuo et al. (2019); Yang and Evans (2019)
	Contribution to a CE	Yang et al. (2018); Khan et al. (2019); Kaddoura et al. (2019); Pieroni et al. (2019)
	Reduction of waste generation	Armstrong et al. (2015); Gelbmann and Hammerl (2015); Arabi et al. (2018)
	Incentive for reuse	Armstrong et al. (2015); Gelbmann and Hammerl (2015)
	Energy consumption reduction	Song and Sakao (2017); Yang and Evans (2019)
	Pollution reduction	Manzini and Vezzoli (2003)
	Better use and efficiency of resources	Yang and Evans (2019)
Benefits to the community	Job creation	Gelbmann and Hammerl (2015); Li, Hua et al. (2015); Kristensen and Remmen (2019)
	Contribution to a more sustainable lifestyle	Gelbmann and Hammerl (2015)
	Affordable goods for low-income groups	Gelbmann and Hammerl (2015)
	Improved employee salary and satisfaction	Yang and Evans (2019)
	Enhanced safety and operator protection	Yang and Evans (2019)
Benefits to the PSS provider	Source of competitive advantage	Manzini and Vezzoli (2003); Gao et al. (2011); Laperche and Picard (2013); Gelbmann and Hammerl (2015); Li, Hua et al. (2015); Karlsson et al. (2018); Mourtzis et al. (2017b); Palmer et al. (2017) ; Boli (2018); Kaňovská and Tomášková (2018); Mourtzis et al. (2018a); Mourtzis et al. (2018b); Mourtzis et al. (2018d); Khan et al. (2019); Olivotti et al. (2019); Rosa et al. (2019b);Annarelli et al. (2020)
	Revenue generation	Lin et al. (2010); Gao et al.(2011); Barquet et al.(2013); Belvedere et al. (2013); Armstrong et al. (2015); Chiu, Kuo, and Kuo (2015); Li, Hua et al. (2015); Rabetino et al.(2015); Szwejczewski et al.(2015); Grubic and Peppard (2016); Arabi et al. (2018); Andriankaja et al. (2018); Junior et al (2018); Mourtzis et al. (2018c); Wan et al.(2018); Olivotti et al. (2019); Kuo et al. (2019); Leoni (2019);Yang and Evans (2019)

	Increased customer satisfaction/loyalty	Pezzotta et al. (2012); Visnjic Kastalli et al. (2013); Li, Hua et al. (2015); Peruzzini et al. (2015); Szwejczewski and Anffinos (2015); Weeks and Benade (2015); Mourtzis et al. (2017); Kaňovská and Tomášková (2018); Mourtzis et al. (2018c, 2017); Basirati et al. (2019); Chiu et al. (2019); Yang and Evans (2019)
	Cost reduction	Tenucci and Supino (2019); Manzini and Vezzoli (2003); Grubic and Peppard (2016); Zancul et al. (2016); Basirati et al. (2019); Rosa et al. (2019b)
	An alternative to adding additional value to products	Manzini and Vezzoli (2003); Kim and Yoon (2012); Barquet et al. (2013); Parida et al. (2014); Mourtzis et al. (2017); Sousa and Da Silveira (2017); Khan et al. (2019)
	Creation of new markets	Manzini and Vezzoli (2003); Hernández Pardo et al. (2012)
	Better customer relationship	Khan et al. (2019)
Benefits to costumers	Cost reduction	Manzini and Vezzoli (2003); Armstrong et al. (2015); Gaiardelli et al. (2014); Arabi et al. (2018) Yang et al. (2018); Rosa et al. (2019b); Yang and Evans (2019)
	Improved product performance and functional capacity	Armstrong et al. (2015); Zancul et al. (2016); Dimitris Mourtzis et al. (2017); Mourtzis et al. (2018c); Khan et al. (2019); Leoni (2019); Basirati et al. (2019)
	Increased efficiency and effectiveness of their products/businesses	Szwejczewski et al. (2015); Grubic and Jennions (2017); Song and Sakao (2017); Grubic (2018)
	Postponement of product replacement	Armstrong et al. (2015); Corvellec and Stål (2017); Khan et al. (2019)
	Risk mitigation	Grubic and Jennions (2018); Grubic (2018)
	Meeting customers' needs	Li et al. (2014); Basirati et al. (2019); Yang and Evans (2019)
	Updated equipment with rapid technological advances	Khan et al. (2019)
	Increased comfort	Manzini and Vezzoli (2003)

Table 4 - Benefits of implementing product-oriented PSS (source: authors' elaboration).

4. Results of the Multiple Case Studies

This section presents the results of the field research. Using *RQ1* as a reference, we initially describe how the agricultural machinery and equipment industry works with environmental sustainability and interrelates with managing the products' life cycle (sub-section 4.1). Next, we describe the perception of the companies about product-oriented PSS (sub-section 4.2).

4.1. Environmental Sustainability and Product Life Cycle Management

Different studies confirm the importance of inserting sustainability orientation in strategic organizational planning (de Medeiros et al., 2018; de Oliveira et al., 2018). There is an understanding in the environmental literature that sustainable product and process innovations depend on this administrative resource (Lee et al., 2018; Saunila et al., 2019), so we investigated whether the cases under analysis include sustainability in their strategic plans.

Except for two organizations, we observed that the others include sustainable actions in their strategic planning. However, we notice that the inclusion of sustainability is often related to reactive rather than proactive practices. As mentioned by Interviewee D, *"The company has its environmental management system, in which all the impacts that the company can bring to the community and the environment are considered. In strategic planning, this is considered"*.

We noticed an understanding of the interviewees about the importance of sustainability for the competitive advantage of their businesses. However, contemplating environmental sustainability practices is more related to external pressures, such as compliance with environmental legislation (Despeisse et al., 2012; Pallaro et al., 2015) and the demands for eco-efficient solutions from customers and society (Batista and de Francisco, 2018; Despeisse et al., 2012) than internal issues, such as moral values (Junsheng et al., 2020; Xie et al., 2019). *"Customers, especially youngsters, are demanding companies to be sustainable"* (Interviewee K). *"I believe that environmental legislation will demand more and more from companies"* (Interviewee F).

In a complementary way, since aspects related to sustainability should be considered in creating and developing new products to reduce the environmental impacts of their production, use, and end of life (Zarte et al., 2019), we investigated how the cases under analysis considered this interrelationship. Although the theme of alignment between environmental sustainability and product life cycle management has been debated since the 1990s in the academic literature, we perceived gaps in the practices of insertion of environmental aspects in developing new products. The same perception was confirmed concerning the inclusion of CE practices.

In summary, among the cases studied, only one of the companies manages the product life cycle oriented to sustainability. Only this company contemplates different alternatives for

reducing environmental impacts in production, use, and end of life phases. The actions involve the use of renewable materials, preference for suppliers that meet environmental and quality standards (for production), optimization of equipment (use), and initiatives with concessionaires for the proper disposal of components (end of life). As mentioned by Interviewee C, *"There is a sustainability process aimed at renewable materials. Also, the product's life cycle is considered, including when it leaves the company and is used by the customer. There is a concern to optimize this equipment".*

The other three companies have product life cycle management partially oriented to sustainability. They have no specific guidelines for environmental issues during the production and end-of-life phase. However, they have actions aimed at use, such as observing product features in the project, which help reduce the use of pesticides or other chemicals that cause environmental impacts. For Interviewee H, *"The products that the company develops are already related to the issue of fertilizers and poisons. So, there is an environmental concern in that sense"*. As mentioned by Interviewee E, *"In the development of new products, we research new technologies as a way to reduce the use of fertilizers or pesticides."* Finally, two companies did not exemplify actions carried out to consider sustainability in managing the product's life cycle.

Regarding the differences observed concerning the positioning of companies in the themes under study, we observed that the behavior depends more on governance characteristics than on size. The two companies that do not include sustainable practices in conducting their business are family businesses. Even though one of them is large and the other is medium-size, none has a structured strategic plan oriented to sustainability. Additionally, we realize that companies with difficulties in guiding strategic planning towards sustainability also have difficulties implementing sustainable actions in the production, use, and end of life of products in a holistic way. Theoretically, a series of studies indicates that organizational culture is an importessentialrce for companies to evolve from reactive practices to proactive practices concerning sustainability and its insertion throughout product life cycle management (de Oliveira et al., 2018; Potrich et al., 2019).

4.2. Perceptions About Product-Oriented PSS

After the initial diagnosis identifying governance and operational practices of product life cycle management in the agricultural machinery and equipment industries, we investigated the respondents' perception of the product-oriented PSS. Initially, we questioned whether they believed that this business model could be adapted to their models to enhance responsible practices. In general, managers believe so, although some are unable to exemplify how this

could happen.

Regarding the more specific information about the product-oriented PSS, we initially identified the services offered in the cases surveyed and how they are offered to customers. From the interviewees' speeches, we identified three different situations: (i) companies that offer package options of products and services; (ii) companies that sell products and offer some service options; (iii) companies that sell products with additional restricted services.

Specifically, Company 2 offers product and service package options to customers. In addition to a collection of pre-established services observing the equipment's life cycle, customers can also choose to purchase additional packages, including, for example, an extended product warranty, a telemetry system for remote monitoring of machinery, maintenance packages, and equipment management and updates. As mentioned by Interviewee D, *"There are packages of products and services offered that vary according to each customer. Larger customers usually purchase an extended warranty package"*.

Cases 3, 4, and 5 do not usually sell product and service packages, but they do offer some services over the lifespan of the products. In addition, customers can choose to hire some additional services. Thus, depending on the company, customers can purchase digital solutions such as a more assertive geolocation signal, telemetry system, and remote equipment calibration. *"We do not sell as a package; the actions of selling products or services are kind of unconnected"* (Interviewee E). *"We do not sell as a closed package. Customers can pay for services when needed"* (Interviewee J).

Finally, cases 1 and 6 sell the products and provide restricted services to their customers. Examples of services available are technical delivery, the offer of spare parts, and maintenance. There is no option for the customer to hire additional services in these organizations. *"The main service we offer is technical assistance, trained technicians monitor the machines. We also offer spare parts"* (Interviewee A).

We can observe that the researched companies offer services more reactively, driven by the customers. They could gain advantages by proactively anticipating customer needs (Motjolopane, 2021). Table 5 summarizes the services that are offered in the cases investigated.

Services	**Company 1**	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**
Technical delivery	✓	✓	✓	✓	✓	✓
Extended warranty		✓				

Maintenance	✓	✓	✓	✓	✓	✓
Training / Consulting		✓	✓	✓	✓	
Upgrades		✓				
Inspection and diagnosis		✓	✓	✓	✓	
Spare parts	✓	✓	✓	✓	✓	✓
Software/license to use		✓		✓		
Documentation	✓	✓	✓	✓	✓	✓
Support	✓	✓	✓	✓	✓	✓
Take back		✓			✓	✓
Remanufacturing		✓			✓	
Recycling		✓				

Table 5 - Services offered by the investigated Brazilian agricultural machinery companies (source: authors' elaboration).

After mapping the services that are made available, we investigated the barriers that companies would face to implementing the product-oriented PSS and how the different stakeholders could benefit from the implementation. In addition, we analyzed which of the good practices previously mapped in the literature are essential for the implementation of product-oriented PSS (Table 6).

Record Unit		Context Unit	Frequency
Barriers		**Some Interviewees' Statements**	
Internal	Difficulty in measuring financial return	*The main difficulty is to present the financial return that the offers can give.* (Interviewee G) *Without a financial return, the company is unable to perform. So, the initial investment is more complicated.* (Interviewee A)	5
	Lack of qualified staff	*The know-how related to this, the knowledge related to it.* (Interviewee G) *Salespeople need to know how to sell packages. Technicians must know how to perform the services.* (Interviewee F)	4
	Resistance to change	*Resistance to change, especially in companies that have always been focused on selling products.* (Interviewee H).	4
External	Lack of good connectivity in the country	*Connectivity is a significant barrier, making it challenging to advance these technologies and services.* (Interviewee C)	1
Benefits		**Some Interviewees' Statements**	
Company	Increased customer satisfaction/loyalty	*I believe in customer satisfaction.* (Interviewee B) *I believe that the main thing is customer loyalty.* (Interviewee J)	6
	Improved company's image	*Image improvement, as it is a sustainable company.* (Interviewee C) *I believe that the main benefit is the company's image.* (Interviewee L)	4
	Differentiation from competitors	*Several customers have already told us that. Nowadays's, the chief differential is not necessarily the products but the service that the company offers* (Interviewee D) *It is possible to offer services for the company to be different.* (Interviewee G)	3
	Revenue generation	*Financial profitability for the company, financial gains.* (Interviewee C)	3
Costumers	Improved product performance and efficiency	*Customers can work more and better with their machines, within a shorter period*. (Interviewee C) *The product will be available when the customer needs it.* (Interviewee F)	4
	Specialized and available attendance	*The customer gets a more specialized service. When the customer needs a service, there is an available dealership; he does not need to have his own structure to perform the services*. (Interviewee D)	3

		When the machine stops or maintenance is required, the customer gets support quickly. (Interviewee F)	
Environment	Proper disposal of waste and components	*There is a large amount of garbage and waste generated and can be appropriately disposed of.* (Interviewee E) *When the service is performed, technicians can bring the used components of the equipment for proper disposal.* (Interviewee F)	4
	Pollution reduction	*The maintenance and control of the product will naturally generate less environmental pollution.* (Interviewee H) *When the machine is working correctly, it saves fuel and reduces pollution.* (Interviewee K)	3
Social	Job creation	*Jobs generation. The company will hire more people from the community to offer the services.* (Interviewee A) *There is the generation of jobs and income for people who work in this area.* (Interviewee C)	2
Good Practices		**Some Interviewees' Statements**	
Market orientation	An approach centered on customer satisfaction	*Everything has to be designed for the customer. We will design the product according to the customer's needs* (Interviewee A) *An approach centered on customer satisfaction for sure.* (Interviewee G)	12
	Collection of customer needs	*It is necessary to collect the customer's needs to satisfy them later.* (Interviewee F) *Collection of customer needs.* (Interviewee G)	6
	Setting goals considering sustainable aspects	*I believe that goal setting considering sustainable aspects is important.* (Interviewee I)	4
Human Resources Strategic management	Good training and development practices	*I think that the question of training and development practices for people is very important.* (Interviewee E) *Training and development are highlights.* (Interviewee C)	7
	Using cross-functional teams	*For the packages' success, the use of multifunctional teams is essential. The more people think, the greater the chance of succeeding.* (Interviewee B) *A multifunctional team is essential.* (Interviewee D)	7
Technology Investment	Using Information and Communication Technology	*The use of technologies is fundamental; it generates important information and data.* (Interviewee I) *I think investment in technology, the use of information and communication technologies.* (Interviewee J)	7
Sustainable product and	Parallel product and service development	*I think that development should be in parallel. Additional services may arise, but when the product is developed, the best is to think about the service packages linked to it*. (Interviewee D)	7

service design		*During product development, think about service opportunities.* (Interviewee H)	
	Development of ways to demonstrate confidence and tangibility to the offer	*Trust and tangibility. If the customer cannot see the benefit, it is more difficult to sell the packages.* (Interviewee B) *I think it is really important to demonstrate that the offer is valid for the customer because if he does not understand that this is a benefit, they will not pay an additional amount. They need to perceive future gains in maintenance time, machine downtime, and reduced refueling time.* (Interviewee F)	7

Table 6 - Barriers, benefits, and good practices (source: authors' elaboration).

In general, most respondents mentioned internal barriers. In only one case, the main barrier mentioned is external, related to the difficulty of connectivity in the country. Additionally, we identified that a large part of the barriers mentioned by the interviewees has already been recognized in the literature through theoretical and empirical studies of companies operating in different sectors, such as those of Laperche and Picard (2013), Zine et al. (2016) e Leoni (2019). Likewise, the benefits cited by the interviewees are consistent with those identified in the systematic literature review. In addition, the analysis of the mentioned benefits is aligned to the findings of Despeisse et al. (2012) on sustainable practices, where the economic benefits and the reduction of environmental impacts predominate over social aspects. For Pallaro et al. (2015), companies may not perceive direct benefits from adopting socially sustainable practices. Finally, when it comes to good practices, all variables mapped in the literature were cited by at least one of the interviewees.

5. Discussion

Based on the results described in sections 3 and 4 of the study, we realized that, although the product-oriented PSS can add to the governance and operationalization of more sustainable life cycle management of agricultural machinery companies, difficulties in organizational culture inhibit its wide adoption in the cases analyzed. Theoretically, other studies have already signaled that eliminating cultural barriers, developing a set of green competencies (such as proactive leadership), and the capacity for critical reflective analysis is fundamental for the successful innovation of sustainable products. In addition, studies in environmental management reinforce the importance of the commitment of top management and orientation towards sustainability so that green and social solutions are possible (de Medeiros et al., 2022). Therefore, observing our results and the findings of other studies, we infer that agricultural machinery companies need to expand the insertion of values related to sustainability beyond operational tactics. There is a need for senior management to insert sustainability dimensions into the strategic orientation of their businesses.

Although most respondents in the investigated cases declare to be aware of the need for sustainable practices in the industry to comply with regulations and market demands, the analysis of the statements elucidates that environmental issues are not a dominant topic in the development of products and services. Management is reactive, not proactive. There is a prevailing economic view in which services are added to strengthen customer relationships and expand the competitive advantage.

Another relevant discussion is the behavior and level of maturity of the Brazilian industry

regarding sustainability. Most companies in Brazil are still underdeveloped in terms of sustainability (Martins et al., 2020). They generally do not adequately integrate sustainable practices into their management systems, and environmental and social aspects are not the top priority of Brazilian companies. Moreover, there is a lack of government incentives and subsidies for investment in socio-environmental issues, a lack of technologies, and inadequate management (Chiappetta Jabbour et al., 2020).

Furthermore, the interviewees demonstrate that they do not understand the extension of the concept of product-oriented PSS. Despite this, the cases studied offer services that can be considered possibilities for product-oriented PSS. Many of the services listed are related to the use of information and communication technologies, mainly through remote monitoring and maintenance. These are essential tools for agriculture to increase yields and efficiency. However, services related to the end of useful life are scarce. There are no indicators to assess the impact of the provision of services on environmental and social performance throughout the life cycle. Using indicators to evaluate sustainability performance is a critical practice, and our results show that this needs to be consolidated. Our results allow us to infer that the process is not yet clearly structured in the Brazilian agricultural machinery and equipment industry. In most cases, PSS offers are designed without considering socio-environmental aspects.

Finally, despite the potential difficulties, considering that most companies surveyed have a structured or partially structured product development process and already offer some services to customers, we consider that they can offer product-oriented PSS. According to Barquet et al. (2013), when the company already has some experience in providing services, the implementation of the PSS is facilitated. In addition, the findings indicate that some types of services may be more appropriate for some companies than for others. For instance, more structured companies can move forward in offering product and service packages based on technology-related solutions, while family businesses or those with fewer resources can initially better structure their processes and offer basic services or those that require a lower financial investment.

6. Proposal of a Conceptual Model for the Adoption of Product-Oriented PSS

Given the above, to clarify which practices can be employed so that the agricultural machinery and equipment industry can qualify the life cycle management of its products sustainably, we have developed a conceptual model (Figure 2). We reinforce that companies with different maturity levels and orientations towards sustainability can use it to design service packages that extend the life cycle, minimize environmental impacts, and increase financial and social

gains. Therefore, we propose that this business model is in line with the principles of CE, especially in the sense of maintaining the value of materials, resources, and products as long as possible, increasing product lifecycle, helping in waste prevention and resource efficiency, and contributing to sustainable production and consumption. Implementing the model may require adapting the existing business model or creating a new one. Therefore, changes may be more straightforward or more complex. In either case, risk management is an effective practice to drive business model innovation (Motjolopane, 2021).

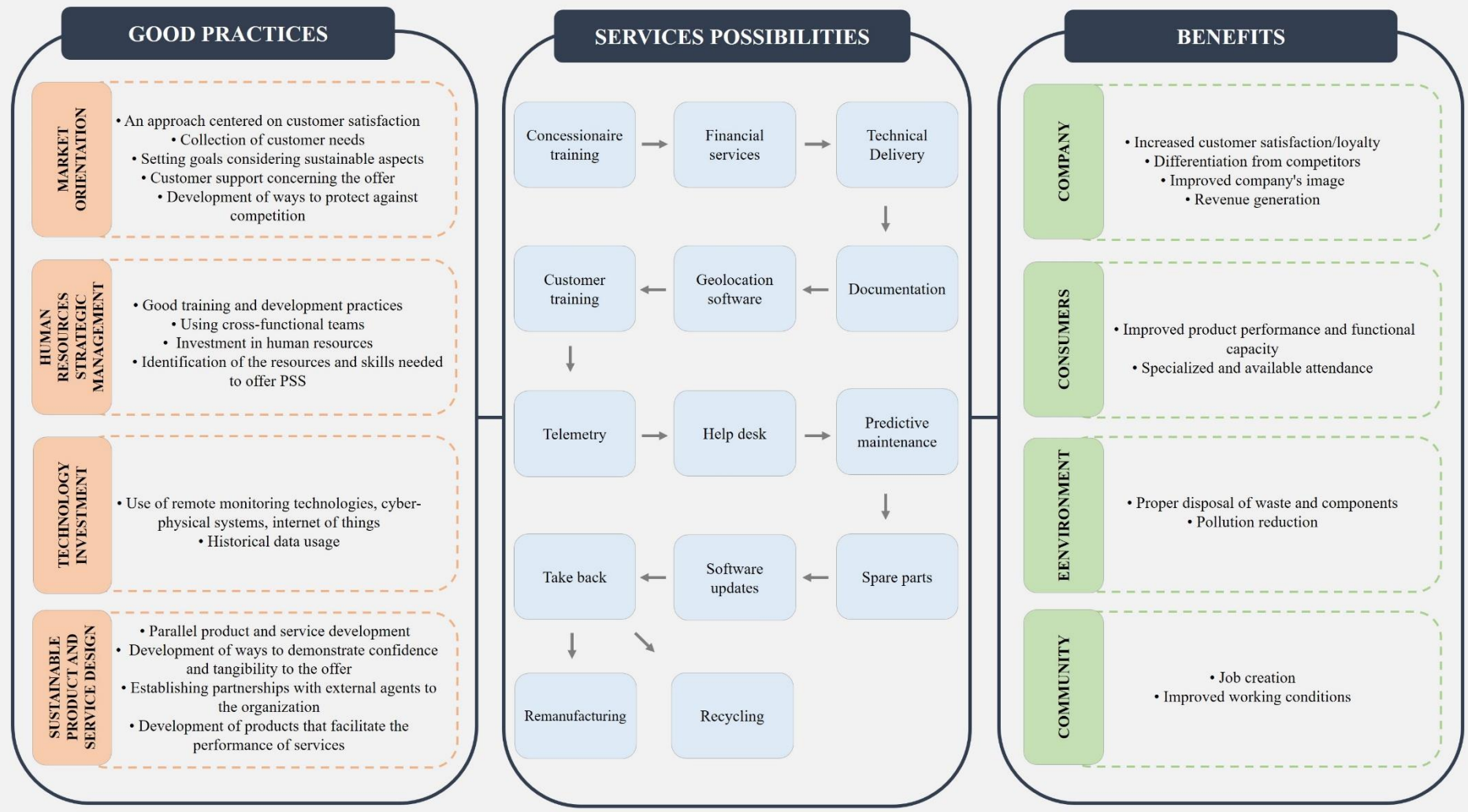

Figure 2 - Conceptual model for adopting product-oriented PSS (source: authors' elaboration).

Aligning the results of theoretical and field research, the conceptual model presents the set of practices that can be developed to facilitate and qualify the development of the product-oriented PSS offer, the sequencing of services that can be offered, and the potential benefits obtained from the suggested practices and inclusion of the proposed services.

Therefore, we suggest that managers initially conduct a diagnosis of the company's current product and/or service development process to understand which good practices are already being carried out. Afterward, it is essential to define strategies for inserting other good practices in the offer development process, according to the company's strategy, considering financial and personnel resources.

In general, best practices related to *Market Orientation* occur mainly in the initial and planning phases, as most practices are focused on understanding customer needs and designing offers according to their needs. It also involves decisions on how to include environmental and social aspects, in addition to economic ones, in the offerings to be developed. Practices related *to Human Resources Strategic management* typically occur in the initial and developmental stages. It involves mainly the use of cross-functional teams composed of members from different departments, with contributions from other stakeholders, such as customers and suppliers. It also requires that the staff responsible for developing the offering and providing the services be adequately trained.

Practices related to *Technology Investment* are usually linked to the phases of offer development and customer use of the products. In this case, it is important to investigate the effect of technology on customer responses (Planel-Ratna and Juwaheer, 2021). Finally, sustainable product and service design practices occur mainly in the offer development and service provision or follow-up phases. In the latter cases, they may involve partnerships with companies to perform some services or with concessionaires, suppliers, or other companies to prevent machinery components from being improperly discarded.

We reinforce that most good practices can occur in different phases, not necessarily those mentioned, depending on the companies' context. After understanding and defining the best practices to be implemented, the conceptual model indicates the services that can be offered through product-oriented PSS. In the proposed conceptual model, services are depicted in the sequential form that usually occurs in agricultural machinery and equipment companies.

Concessionaire training is mainly conducted to teach the staff how to sell PSS to customers and provide the services when applicable. Financial services involve offering equipment financing options, usually through the existence of a partner or own bank. In the technical delivery, a trained team visits the customer and carries out training on the use of the equipment

and aspects related to maintenance. In the case of documentation, all machines should be delivered with a manual containing information regarding the operation and component replacement. Generally, the same information can also be made available online on the companies' websites.

Companies can offer digital solutions, such as a more precise geolocation service, which generates product savings and higher efficiency for the equipment. Costumer training for the use of digital services and software is essential. Telemetry allows monitoring the equipment and performing predictive maintenance and machine corrections remotely. Regarding the help desk, customers can contact the concessionaire directly, the company itself, or the after-sales team, depending on their needs. Through telemetry or other techniques, predictive maintenance of machines can be performed. Usually, companies can offer spare parts together with maintenance or repair activities or stand-alone service when the customer requests it. Software updates are essential to keep the equipment working correctly or add new functionalities. Finally, take-back service can be offered to remanufacture or recycle components or equipment parts.

We observed that the suggested services differ in terms of complexity. Help desk, offering documentation and spare parts are usually simple. Services such as technical delivery, training, corrective maintenance, and equipment financing have a greater degree of complexity. Other services such as telemetry, predictive maintenance, software supply, and updates require more significant investment in technologies and human resources to be implemented. Finally, it is understood that services at the end of the product’s useful life (return, remanufacturing, recycling) usually will require the establishment of partnerships with agents external to the companies (concessionaires, suppliers, recycling companies, etc.) or the restructuring of organizational processes to establish suitable alternatives for the machines/components used. Additive manufacturing can help in end-of-life services and the design of spare parts and products (Righettini and Strada, 2021).

Finally, assessing the performance of the PSS is important to support the analysis of the circumstances in which the offers lead to the benefits mentioned earlier. To qualify the environmental potential of the offers, we suggest that environmental performance indicators be considered. As an example, we cite the use of indicators for waste generation, gas and pollutant emissions, material consumption, and water and energy consumption (Chou et al., 2015; Kravchenko et al., 2019), in addition to the usual market indicators used by companies that adhere to the product-oriented PSS, such as customer satisfaction and retention.

7. Conclusions

To fill the gap on how companies in the agricultural machinery industry can develop sustainable offerings through product-oriented PSS, we initially investigated how this industry perceives environmental sustainability and product-oriented PSS. Then, we identified practices that can be suggested so that companies can qualify the life cycle management of their products in a sustainable way. Thus, this article presented a qualitative study carried out through a systematic literature review complemented by multiple case studies, resulting in the proposition of a conceptual model for product-oriented PSS implementation in the agricultural machinery sector.

Our article listed possibilities for product-oriented PSS that can be aggregated for ordinary companies to guide their business towards sustainable practices and the benefits of adopting product-oriented PSS. Our findings reveal that the agricultural machinery and equipment industry perceives environmental sustainability and the product-oriented PSS as necessary. However, socio-environmental issues are not prioritized in developing its products and services. There are barriers, especially cultural ones, that support this behavior in most of the analyzed organizations. Our main conclusion is that companies in the agricultural machinery and equipment sector have advanced in offering services to their customers. Still, there are ample opportunities for improvement, especially for offering packages of products and services and considering the PSS as a way to obtain financial returns and contribute to environmental and social sustainability. Therefore, a conceptual model to support sustainable PSS implementation was proposed.

From a theoretical point of view, the study contributes to theoretical knowledge by advancing discussions on the product-oriented PSS, particularly on its potential to promote CE and sustainable management practices. We advance in the recognition of product-oriented PSS contribution to the extension of the product life cycle and reduction of waste generation. The proposed conceptual model also enriches the research related to sustainable production and consumption alternatives.

Additionally, the various services that can be offered in product-oriented PSS were summarized, which, in addition to helping to extend the life of the products, can reduce environmental impacts, especially those caused by the inappropriate use and disposal of products. It was also identified that - besides companies and customers - the environment and society could benefit from the development of the PSS. Furthermore, good practices that help develop offers were identified and categorized into four dimensions: market orientation,

strategic people management, investment in information technology, and sustainable design of products and services.

Besides that, we investigated sustainable and product-oriented PSS issues in the agricultural machinery industry empirically and in greater depth. We improve the understanding of how this industry perceives environmental sustainability and product-oriented PSS. Our research contributes to the theory, helping to overcome the lack of holistic field investigations in this sector. The contributions add value to current research on sustainability in the agricultural machinery industry and may guide future research on the topic. The research demonstrates how the agricultural machinery industry can contribute to more sustainable agriculture through product-oriented PSS implementation.

As practical advances, we highlight the proposed conceptual model, allowing companies to expand their understanding and adherence to product-oriented PSS practices. The concept model serves as an aid for companies to have guidance and better clarity about the necessary procedures for implementing product-oriented PSS. We highlighted important factors that must be considered when developing the offers.

Additionally, the study presents relevant encouragement and help to companies operating in the agricultural machinery and equipment sector that wish to implement the product-oriented PSS and develop CE practices. In this sense, it helps companies consider not only economic but also environmental and social aspects in developing their products. Given the importance of agricultural equipment and machinery in achieving sustainable agriculture, the research contributes to the rethinking of agriculture systems toward sustainable forms of production.

We also emphasize that through the mapped benefits, companies can develop advertising campaigns that demonstrate the environmental and social potential of PSS offers and the benefits for customers when purchasing them. This can help to encourage customers to more sustainable purchase and consumption behaviors, given the responsibility that companies also have in stimulating sustainable consumption.

The study also provides implications for policymakers and regulators. Our results suggest that government should include policy priorities that encourage companies to undertake socio-environmental initiatives. Companies should be encouraged to pay more attention to the environmental impact of their products. Also, it is crucial to raise customers' awareness about their role in sustainable consumption. Finally, there are opportunities to assist companies and customers regarding actions at the end of life of the products.

As limitations of this work, we emphasize that the field study prioritized medium and large agricultural machinery and equipment industry companies located in Brazil. Therefore, future

studies can be conducted with a more significant number of companies from different countries to validate the findings. As for the proposed conceptual model, we highlight as a limitation the fact that the elements of the proposed model were not empirically tested. An opportunity for future research is to pursue quantitative data and statistical analysis that would allow running Exploratory Factor Analysis and Confirmatory Factor Analysis.

Acknowledgments and Funding: This work was supported by the National Council for Scientific and Technological Development (CNPq, grant number 308723/2017-1) and the Higher Education Improvement Coordination (CAPES, grant number 88887.608225/2021-00). The authors would like to thank CNPq, CAPES, and the interviewees who contributed to this research.

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Articles selected by journals (source: authors' elaboration)

Journal	Number	Authors
Journal of Cleaner Production	16	Manzini and Vezzoli (2003); Maxwell and Van der Vorst (2003); Gelbmann and Hammerl (2014); Chou, Chen and Conley (2015); Laperche and Picard (2013); Armstrong et al. (2014); Gaiardelli et al. (2014); Corvellec and Stål (2017); Song and Sakao (2017); Kjaer et al. (2018b); Glatt et al. (2019); Kristensen and Remmen (2019); Rosa, Sassanelli and Terzi (2019b); Yang and Evans (2019); Zeeuw Van der Laan and Aurisicchio (2019); Annarelli, Battistella and Nonino (2020)
Sustainability	7	Hernández Pardo, Bhamra and Bhamra (2012); Adam (2018); Kaddoura et al. (2019); Kwon, Lee and Hong (2019) Pieroni, McAloone and Pigosso (2019); Zhao et al. (2019)
CIRP Journal of Manufacturing Science and Technology	5	Pezzotta, Cavalieri and Gaiardelli (2012); Resta et al. (2015); Bertoni et al. (2016); Andriankaja, Boucher and Medini (2018); Khan, West and Wuest (2019)
International Journal of Production Research	5	Belvedere, Grando and Bielli (2013); Szwejczewski, Goffin and Anagnostopoulos (2015); Grubic and Jennions (2017); Karlsson, Larsson and Rönnbäck (2017) and Chiu, Chu and Kuo (2019)
Computers in Industry	3	Alix; Zacharewicz (2012); Wan et al. (2017); Grubic (2018)
International Journal of Product Lifecycle Management	3	Palmer et al. (2017); Heo, Lim and Kim (2018); Mourtzis, Vlachou and Zogopoulos (2018)
International Journal of Operations & Production Management	3	Sousa and da Silveira (2017); Raja et al. (2018); Ayala, Gerstlberger and Frank (2019)
IFAC PapersOnLine	2	Maleki, Belkadi and Bernard (2018); Mourtzis, Angelopoulos and Boli (2018)
Industrial Marketing Management	2	Barquet et al. (2013); Rabetino et al. (2015)
Journal of Intelligent Manufacturing	2	Gao et al. (2011); Shokohyar, Mansour and Karimi (2014)
Journal of Manufacturing Technology Management	2	Bandinelli and Gamberi (2012); Grubic and Peppard (2016)
Production Planning & Control	2	Alghisi and Saccani (2015); Yang et al. (2018)
The International Journal of Advanced Manufacturing Technology	2	Mourtzis et al. (2018); Wan et al. (2018)
Advances in Science, Technology and Engineering Systems Journal	1	Wirawan, Yudoko and Lestari (2018)
African Journal of Business Management	1	Lin et al. (2010)
AGRIS on-line Papers in Economics and Informatics	1	Kaňovská and Tomášková (2018)
Applied Sciences	1	Suh (2019)
Asia Pacific Journal of Information Systems	1	Basirati et al. (2019)
Benchmarking: An International Journal	1	Zine et al. (2016)
Business Process Management Journal	1	Zancul et al. (2016)

California Management Review	1	Visnjic Kastalli, Van Looy and Neely (2013)
EuroMed Journal of Business	1	Leoni (2019)
IEEE Transactions on Systems, Man, and Cybernetics: Systems	1	Li, Hao et al. (2015)
Information Systems and e-Business Management	1	Olivotti et al. (2019)
International Journal of Agile Systems and Management	1	Peruzzini, Marilungo and Germani (2015)
International Journal of Computer Integrated Manufacturing	1	Li et al. (2014)
International Journal of Design	1	Sayar and Er (2018)
International Journal of Industrial Engineering	1	Chiu, Kuo and Kuo (2015)
International Journal of Production Economics	1	Ayala et al. (2017)
International Journal of Sustainable Engineering	1	Arabi, Mansour and Shokouhyar (2017)
Journal of Computational Design and Engineering	1	Tran and Park (2014)
Journal of Computing and Information Science in Engineering	1	Mourtzis, Papatheodorou and Fotia (2018)
Journal of Design Research	1	Sutanto et al. (2015)
Journal of Engineering Manufacture	1	Baines, Lightfoot and Kay (2009)
Journal of High Technology Management Research	1	Li, Hua et al. (2015)
Journal of Industrial Ecology	1	Kjaer et al. (2018a)
Journal of Management and Governance	1	Tenucci; Supino (2019)
Journal of Manufacturing Science and Engineering	1	Mourtzis, Vlachou and Zogopoulos (2017)
Journal of Manufacturing Systems	1	Mourtzis, Fotia and Vlachou (2017)
Journal of Mechanical Engineering Science	1	Sheng, Liu and Xu (2016)
Journal of Operations Management	1	Visnjic Kastalli and Van Looy (2013)
Mathematical Biosciences and Engineering	1	Li, et al. (2019)
Operations Management Research	1	Neely (2008)
Quality Management Journal	1	Sharma and Kumar (2016)
Research-Technology Management	1	Parida et al. (2014)
Resources, Conservation & Recycling	1	Kuo et al. (2019)
Revista de Administração de Empresas	1	De Souza Junior, Torres Junior and Miyake (2018)

Service Business	1	Kim and Yoon (2012)
Service Science	1	Adam, Strähle and Freise (2017)
Systems	1	Pirayesh et al. (2018)
Technology in Society	1	Weeks and Benade (2015)
The Design Journal	1	Sayar and Er (2019)
The TQM Journal	1	Haber and Fargnoli (2019)
Total	**94**	

Data collection instrument (source: authors' elaboration)

Research Question	Variables
RQ1: How does the agricultural machinery and equipment industry perceive environmental sustainability and product-oriented PSS?	1. How does the life cycle management of the agricultural products produced take place? 2. What is the company's position in relation to sustainability? Does strategic planning include sustainability? Can you exemplify? 3. Do you believe that actions focused on sustainability are important? Why?
RQ2: What practices can be suggested so that the agricultural machinery and equipment industry can qualify the life cycle management of its products to contribute to CE?	4. Have you ever heard of a product-oriented product-service system (PSS)? What is your understanding of this approach? 5. Does the company currently offer any service to customers? If so, what are the main services and how are they offered? 6. What barriers to implementing product-oriented PSS do you believe would occur in your company? Why? 7. What benefits do you understand that can be obtained from the implementation of the product-oriented PSS? 8. From the list of good practices presented, which ones do you believe are essential for the successful implementation of product-oriented PSS in your company?

Possibilities for using product-oriented PSS (source: authors' elaboration)

Services	Description	Examples
Installation	The PSS provider offers to install the product (Gaiardelli et al., 2014). Some products require careful and complex installation (Szwejczewski et al., 2015).	- Company that offers installation service for elevator (Song and Sakao, 2017); - Company that sells air separation units and also provides installation of the products (Yang et al., 2018); - Company that sells modular carpet tiles and offers installation services (Annarelli et al., 2020); - Company that sells industrial printers and performs the installation service (Szwejczewski et al., 2015); - Manufacturer of professional appliances for restaurants that offers installation and product initialization services (Alghisi and Saccani, 2015); - Manufacturer of electronic gate access systems that offers system installation services (Weeks and Benade, 2015).
Maintenaince and repair	The PSS provider offers the product maintenance service, which can influence the consumption of resources during use and the product's useful life (Kjaer et al., 2018b).	- Manufacturer of industrial robots that provides a maintenance service package that includes regular inspections and diagnostics, preventive maintenance, remote condition monitoring and reconditioning services (Parida et al., 2014); -Company in the fashion sector that offers clothing repair/maintenance service to improve its fit for some years (Armstrong et al., 2014; Adam et al., 2017; Corvellec and Stål, 2017; Adam, 2018); - Company that sells copy machines and offers customers related maintenance and support services (Gao et al., 2011); - Furniture company that provides repair services to items such as locker and doors, increasing the life of its components (Kaddoura et al., 2019); - Mold manufacturer for the mass production of plastic or metallic parts that offers mold maintenance service (Mourtzis and Vlachou, 2017; Mourtzis et al., 2017a; Mourtzis et al., 2018b; Mourtzis et al., 2018c); - Thermoforming machine manufacturer that offers maintenance and technical assistance services (Barquet et al., 2013); - Company that manufactures professional appliances for professional and consumer sectors (eg: hotels, health institutions) that offers maintenance plans for its products (Alghisi and Saccani, 2015); - Company that sells machine tools and performs maintenance services (Wan et al., 2018); - Company that sells digital products and offers maintenance and repair services (Chiu et al., 2015); - Maintenance and repair of appliances, computers, laser printers, jewelry, watches (Lin et al., 2010); - Furniture manufacturer that offers a package of continuous maintenance services (Pieroni et al., 2019); - Company that sells bearings and lubrication systems and performs maintenance service (Grubic and Peppard, 2016; Grubic and Jennions, 2017); - Elevator company that provides periodic product maintenance service (Wan et al., 2017); - Manufacturer of industrial equipment that offers maintenance services with different degrees of coverage (Kastalli and Van Looy, 2013; Kastalli et al., 2013); - Manufacturer of road construction equipment that offers maintenance services (Bertoni et al., 2016); - Furniture company that offers upholstery cleaning and upholstery service (Sayar and Er, 2019).
Updates	The PSS provider offers product update service to extend its life	- Computer manufacturer that offers computer update service (Maxwell and Van der Vorst, 2003); - Cell phone software update (Sutanto et al., 2015); - Machine tool company that rebuilds or updates the machines, letting them act as new machines (Gaiardelli et al., 2014);

	cycle and postpone replacement (Khan et al., 2019). Improvement of product's capacity and functionality (Zine et al., 2016).	- Construction company that provides ecological update services for homes using sustainable principles during the update process (Gaiardelli et al., 2014); - Capital equipment companies (aircraft, trains) that offer upgrading of their components, as an alternative to replacing equipment (Khan et al., 2019); - Company that sells gas generator offers technological update service (Yang and Evans, 2019); - Company that sells compressors and pumps for the oil and gas industry and offers update services (Resta et al., 2015); - Company that produces turbines and compressors and offers equipment update service (Bandinelli and Gamberi, 2012).
Training and Consulting	The PSS provider offers technical support training to customers (Parida et al., 2014), improving the efficiency of the product during use (Laperche and Picard, 2013; Gaiardelli et al., 2014). Depending on the PSS offered, the training can be directed to other companies or the final consumer (Laperche and Picard, 2013). Offer service consulting regarding the use or efficiency of the product (Wirawan et al., 2018).	- Tool manufacturer that offers a training program for users and support materials (such as user manual) (Parida et al., 2014); - Company that offers training in the correct use of hemodialysis devices (Haber and Fargnoli, 2019); - Company that sells hairdryers with a hair treatment service package and offers training in the proper use of the product, which allows it to offer a better professional hair treatment service (Kwon et al., 2019); - Company that sells harvesters and offers personnel training service throughout the life of the machine (Glatt et al., 2019); - Building materials company that created a training center to pass on information and training on products and their use to other companies (B2B) (Laperche and Picard, 2013); - Automotive company that develops ecological driving training courses for the final consumer (Laperche and Picard, 2013); - Aircraft company that offers training services for maintenance engineers (Szwejczewski et al., 2015); - Industrial estate company that offers advice on product use or efficiency in activities such as inventory control, company configuration, organizational management, waste treatment, maintenance (Wirawan et al., 2018); - Company that sells communication systems and offers consulting services (Neely, 2008).
Spare parts and consumables delivery	The supplier PSS delivers consumables and original spare parts, which can be supplied together with maintenance and repair activities or as an independent service (Gaiardelli et al., 2014).	- Supply of spare parts for smartphones, white goods, forklifts and warehouse equipment (Annarelli et al., 2020); - Elevator company that provides spare parts for its products (Wan et al., 2017); - Aircraft company that quickly supplies spare parts (Szwejczewski et al., 2015). - Manufacturer of engineering equipment that offers replacement parts for its products (Raja et al., 2018); - Company that sells transformers and offers replacement parts for its products (Li et al., 2014; Li, Hao et al., 2015); - Companies that sell industrial products to different sectors and offer replacement parts for their products (Rabetino et al., 2015)
Take back	The PSS provider offers an after-sales return service, allowing product parts and materials to enter new applications, replacing other products and materials (Kjaer et al., 2018a).	- Clothing companies that offer used clothes return service. Clothing items can be returned in exchange for a coupon for new purchases (Armstrong et al., 2014; Adam et al., 2017; Corvellec and Stål, 2017; Adam, 2018); - Company that offers the service of returning used shoes and offers a discount for the purchase of a new item (Hernández Pardo et al., 2012); - Furniture company that removes products at the end of their useful life, renovates the furniture and makes it available for new sales (Pieroni et al., 2019); - Company that offers return service for old furniture (Gelbmann and Hammerl, 2014);

	The return service can influence the treatment at the end of the product's useful life (Kjaer et al., 2018b).	- Company that sells smartphones and collects the product at the end of its useful life or when the customer wants to change the product (Annarelli et al., 2020); - Cosmetics company that exchanges obsolete resources for a free product (Van der Laan and Aurisicchio, 2019); - Kitchen appliances manufacturer that offers a return service for used items (Chou et al., 2015).
Recycling	The PSS supplier removes the product and provides recycling / dismantling services (Gaiardelli et al., 2014).	- Aircraft dismantling service (Laperche and Picard, 2013); - Building materials company that created a system to collect and recycle plaster waste (Laperche and Picard, 2013); - Company that sells modular tiles and offers removal and recycling services at the end of the product's useful life (Annarelli et al., 2020); - Garment companies that collect and recycle clothing items (Corvellec and Stål, 2017). - Company that sells toys and offers a recycling service (Alix and Zacharewicz, 2012); - Company offering recycling service for CNC machine tools (Sheng Liu and Xu, 2016).
Remanufacturing	The PSS provider sells remanufactured/refurbished or reconditioned products for existing products (Gaiardelli et al., 2014).	- Company that offers a new machine from an old product that has been dismantled and rebuilt from the start to include all necessary updates (Gaiardelli et al., 2014); - Company that sells agricultural machinery (harvester) and offers remanufacturing service (Glatt et al., 2019); - Company that offers remanufacturing service for CNC machine tools (Sheng et al., 2016); - Manufacturer of solvent recycling machines that offers remanufacturing services for equipment (Zancul et al., 2016).
Extended warranty	The PSS provider offers warranty services to convince the customer to keep the product in use for a longer period (Shokouhyar, 2017).	- Company offering extended warranty for notebooks (Shokohyar et al., 2014; Shokouhyar, 2017); - Companies that sell kitchen equipment, domestic washing machines and passenger cars and offer extended warranties for their products (Szwejczewski et al., 2015); - Company that sells transformers and offers extended warranty (Li et al., 2014; Li, Hao et al., 2015).
Inspection and diagnosis	The PSS provider offers customer support by providing inspection services and on-demand diagnostics (Gaiardelli et al., 2014).	- Company offering machine tool monitoring service, in which real factory information is provided about the product's behavior to be used to carry out preventive maintenance based on conditions (Mourtzis et al., 2017b); - Company that sells bearings and lubrication systems and performs remote monitoring service (Grubic and Peppard, 2016; Grubic and Jennions, 2017; Grubic, 2018); - Automotive company that installs sensors in vehicles for monitoring automotive conditions (Lin et al., 2010; Sayar and Er, 2018; Chiu et al., 2019); - Company that produces turbines and compressors and offers remote monitoring and diagnosis services (Bandinelli and Gamberi, 2012); - Company that sells gas generator and offers remote monitoring service (Yang and Evans, 2019); - Company that sells a dryer with additional sensors and components, which allows monitoring the machine condition, providing advice to users on how to improve the efficiency of the machine (Palmer et al., 2017); - Company that sells lubricants and through a mobile chemical laboratory directly checks the customer's industrial machines for the lubricants' performance and environmental impact, controlling noise, vibrations, or other unwanted industrial effects (Manzini and Vezzoli, 2003). (Manzini and Vezzoli, 2003).

Home delivery	The PSS supplier delivers the product to the customer's home (Gaiardelli et al., 2014).	- Distribution of detergents for home delivery, in which each family uses suitable containers and pays only for the amount of detergent desired (Manzini and Vezzoli, 2003); - Distribution and logistics service to ensure that global transport impacts the environment as little as possible (Gaiardelli et al., 2014).
Financial services	The PSS provider offers financial support to customers (eg: financing) (Gaiardelli et al., 2014).	- Company that sells white goods and offers financing options (Annarelli et al., 2020). - Company that sells transformers and offers financial services (Li et al., 2014; Li, Hao et al., 2015).
Documentation	The PSS provider provides documentation regarding the installation, use, maintenance, repair and disassembly of a product (Gaiardelli et al., 2014).	- Aircraft company that provides documentation that includes Aircraft Flight Manual and Flight Crew Operation Manual (Szwejczewski et al., 2015); - Company that sells kitchen equipment and provides online documentation to users on its website (Szwejczewski et al., 2015).
Online support, help desk	The PSS provider provides information and assistance to the customer by phone, email or internet (Gaiardelli et al., 2014).	- Company in the field of engineering and industrial training that offers a combination of product (class materials in the form of files in PDF format) and services (support activity). Each PDF file is sold with a built-in tracking code, which allows to track which file is searched by each customer at the time the customer requests support (Tran and Park, 2014); - Company that produces turbines and compressors and has a customer service center (Bandinelli and Gamberi, 2012); - Industrial printer company that offers online support for factories and distributors (Szwejczewski et al., 2015); - Companies that sell industrial products to different sectors and offer technical support services (Rabetino et al., 2015); - Solvent recycling machine manufacturer that offers telephone support to customers (Zancul et al., 2016).
Additional services	The PSS provider offers a software or use license along with its products.	- Company that operates in the metallurgical industry and sells a solution that consists of a turning tool with a programming strategy (software) for the machines (Karlsson et al., 2017); - Dental equipment company that provides a licensed software service, which makes the equipment easy to use for new users (Ayala et al., 2017); - Aircraft company offering software to help airlines manage their aircraft fleets effectively (Szwejczewski et al., 2015).