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Triple Bottom Line impacts of traditional Product-Service Systems models: Myth or truth? A Natural Language Understanding approach

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ABSTRACT

Currently, there is in the literature a debate concerning the real impact of Product-Service Systems (PSS) models on society. It is now stated that PSS does not necessarily lead to sustainable solutions in practice from a Triple Bottom Line (TBL) perspective. On the other hand, a promising approach, i.e. the Sustainable Product-Service Systems (SPSS) approach, has received attention from scholars within this debate. However, due to the novelty of this discussion, there is insufficient understanding of the synergies and divergences between both approaches regarding the potential to deliver TBL solutions to society. To address these lacks, this study examines the synergies and divergences between PSS and the emerging SPSS to deliver TBL solutions to society. Qualitative and quantitative research approaches were adopted to address the research questions. First, a structured literature review was employed. The literature analysis was segmented into two distinct periods (i.e., first period from 1990 to 2009, and the second period from 2010 to 2021). Next, the Natural Language Understanding (NLU) tools based on Artificial Intelligence (AI) and Neural Networks were applied to analyse the conceptual definitions retrieved from the relevant literature and extract new knowledge regarding both approaches. Third, the patterns of new knowledge were analysed against the literature in the area leading to research findings. Overall, findings indicate that, from a TBL perspective, SPSS is an emerging and promising approach in which the environmental and social dimensions are more salient than in the traditional PSS models. The study also unveils the central concepts related to both approaches in the extant literature. The article extends the current knowledge on PSS and SPSS, guiding the research communities interested in this area and unlocking the present and future challenges towards an effective sustainable-oriented economy. This article is a pioneering study to examine how the PSS and SPSS concepts have advanced towards TBL solutions in society.

1. Introduction

Are the Product-Service Systems (PSS) really sustainable for society? Are the Sustainable Product-Service Systems able to deliver actual financial results for companies? Nowadays, it is notable that PSS models are still not widely comprehended and accepted by firms and different research communities (Rabetino et al., 2018; Annarelli et al., 2016). As a consequence, there is currently a debate concerning the real impact of PSS on the sustainability dimensions (social, environmental and economic) and the idea that PSS business models are not, in fact, intrinsically sustainable as originally expected.

Previous studies have shown that a PSS business might adversely affect environmental issues while harvesting only economic benefits (Tseng et al., 2019a, 2019b; Barquet et al., 2016b; Tukker, 2015; Boucher et al., 2016; Doualle et al., 2016). However, recent evidence reported that: "A gap in the literature remains; most studies that treat

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PSS business models do not mention their relation to sustainability. In addition, different studies take for granted that implementing PSS leads to benefits in the three sustainability dimensions. PSS business models can even have a negative effect on the environment while maintaining only economic benefits." (Barquet et al., 2016b, p. 436).

Conceptually, PSS can be defined as a system of products, services, network players, and supporting infrastructure that continuously strives to be competitive, satisfies customer needs, and has a lower environmental impact than traditional business models (Goedkoop et al., 1999). The PSS concept was initially considered a promising initiative with a positive influence on sustainable production and consumption patterns. However, it is now thought that PSS does not necessarily lead to practical and sustainable solutions and results (Boucher et al., 2016).

Consequently, this lack of trust in PSS's environmental friendliness has resulted in a division into two main research streams in the literature, as evidenced by different research communities. On the one hand, there are the research communities that are focused on sustainability aspects of PSS, dealing primarily with the analyses of the environmental and social impact of the product-related services business. On the other hand, there are research communities that are focused on business and strategy perspectives while almost completely ignoring aspects of sustainability (Annarelli et al., 2016). Recent comprehensive literature reviews also reinforce the arguments of fragmentation of research on the subject. For example, a recent study found that PSS, solution business and service science are the three main servitisation-related research communities (Rabetino et al., 2018).

Controversially, the extant literature also emphasises the imperative urgency for shifting from unsustainable societal and dangerous production patterns to more sustainable ones (Yip and To, 2021; Liu et al., 2021; Rese et al., 2009; Tukker, 2004). In this sense, it is noted that since the first studies, the PSS business models have been labelled as environmentally-friendly business models integrating both the business and the sustainability aspects. Nevertheless, the literature has recently included consistent discussions on whether PSS can deliver the expected benefits, mainly concerning environmental aspects (Negash et al., 2021; Annarelli et al., 2016). Consequently, there is a debate on the sustainable impact of PSS and its role as part of innovative sustainable systems in society (Hernandez, 2019; Boucher et al., 2016; Li et al., 2012).

More recently, a promising approach, named Sustainable Product-Service Systems (SPSS), has been investigated (de Jesus Pacheco et al., 2019; Kuo et al., 2019; Wang et al., 2020; Vezzoli et al., 2015). While various definitions regarding SPSS have emerged in the literature, this paper adopts the definition suggested by Barquet et al. (2016b, p. 436), who defined SPSS as "an approach to achieve benefits in the three dimensions of sustainability". However, extant literature demonstrates a limited body of knowledge examining the synergies and divergences between PSS and the emergent SPSS business models comparatively (Liu et al., 2021; Negash et al., 2021; Tseng et al., 2019a, 2019b). Given the complex challenges imposed by sustainability issues (Negash et al., 2021; Hernandez, 2019), this study advocates that it is essential for scholars, practitioners and policymakers to understand better the real meaning, distinctions and benefits of PSS and SPSS models. Thus, we enter into this debate, and, specifically, this research provides insights and answers to the following research questions:

RQ 1. How have PSS and SPSS concepts advanced over time towards TBL solutions in society?

RQ 2. What are the main synergies and divergences between PSS and SPSS methodologies to deliver TBL solutions to society?

By examining these relevant questions involving the meaning of both PSS and SPSS, this study offers scholars and practitioners a more precise picture of the attributes of synergies and divergences between these approaches. This distinction is relevant because it can guide new research and facilitate the practical diffusion of sustainable business models in companies and society. The central hypothesis advocated in this research is that a consistent look at the evolution of the original definitions of PSS and SPSS provided by different research communities could help us to understand better and clarify these knowledge gaps between and misinterpretations of both approaches. Different methods have been applied to answer the research questions. Firstly, we employed a literature review to extract from previous conceptual published papers (e.g., literature reviews, systematic reviews, state of the art and surveys) the main original definitions of PSS and SPSS since their origins. This data collection stage allowed us to analyse original definitions and the evolution of definitions for both approaches over time. We then applied Natural Language Understanding (NLU) tools, a collection of Application Programming Interfaces (APIs), which performs textual analysis through Natural Language Processing (NLP). In this stage of the research, six key parameters for NLP were applied to perform the textual analysis of the definitions of PSS and SPSS to extract knowledge.

The main theoretical and practical contributions and results of this research are outlined in the following, including a brief description of our approach. First, a comprehensive collection of definitions of PSS and SPSS and their development over time was performed. Second, NLU algorithms were applied for automated analysis of the content of these definitions clarifying the synergies and divergences between the approaches. A set of PSS and SPSS definitions were compared by examining three recognised categories of information and parameters employed in scientific research using NLU algorithms: (i) Extraction rules: Entities, keywords and concepts; (ii) Classification rules: Sentiment and Hierarchy analysis; (iii) Linguistic analysis: Semantic roles. Third, we captured a set of conceptual evidence regarding the meaning and benefits of PSS and SPSS from research communities dedicated to both approaches and insights from recent studies. Taken together, our integrative findings suggest that SPSS may be considered a more advanced approach to use when it comes to the environmental and social perspective of sustainability compared with traditional PSS models.

To the best of our knowledge, this is one of the first academic attempts in the area oriented towards exploring the debate concerning the TBL impact of PSS in the light of emergent SPSS models using robust methods such as the NLP algorithms. Furthermore, this research contributes to extending the current theoretical framework in the PSS field, thus guiding the scientific communities interested in this domain to unlock the present and future challenges towards an improved sustainable-oriented economy.

The remainder of this paper is structured as follows. Section two details the research methods and the data collected in the study. Section three demonstrates the findings from the literature review and discusses the application of the Natural Language Understanding algorithms. In section four, a detailed discussion and research implications summarise the limits of PSS and outline the necessary transition towards SPSS business models. Finally, section five provides the conclusions, limitations and research agenda of the theme.

2. Materials and methods

2.1. Research design

This study aims to discover how PSS and SPSS methodologies have advanced over time to result in TBL-oriented business solutions in society. The research design was organized in three main phases to answer the research questions guiding the study. The first phase, dedicated to data collection, consisted of a literature review to identify and select the main original conceptual definitions for both PSS and SPSS. In the second phase of the study, we applied a set of NLU tools to analyse the conceptual definitions retrieved. Lastly, the analysis and synthesis of the results were performed. These two last phases were the actual data analysis of the research results.

The main procedure by which data was collected was the literature review. The objective of the literature review was to identify the

conceptual and formalized definitions for both PSS and SPSS, which is the interest of our research. One of the advantages of the literature review is to afford an understanding of the state of the art of a research domain and aid in identifying valuable knowledge (Dresch et al., 2015; Tranfield et al., 2003). Previous studies argue that literature review studies can contribute to reducing the presence of bias while, simultaneously, the legitimacy of data analysis is enhanced (Reim et al., 2015; Cook et al., 1997).

In the subsequent research stage, we applied the NLU tools based on AI and Neural Networks to perform the data analysis. The NLU was implemented to analyse the conceptual definitions of PSS and SPSS retrieved from the relevant papers selected during the literature review. In this research stage, the capacity of AI and Neural Networks algorithms in discovering knowledge was applied to extract useful information from the definitions of PSS and SPSS to understand convergences and divergences regarding both approaches. Finally, the knowledge patterns were discussed in light of the recent literature in the area. In this research stage, the chain of evidence from research communities dedicated to PSS and SPSS, and the recent literature, were captured and included in the discussions. The study was based on the conceptual framework and a research protocol (Dresch et al., 2015; Moher et al., 2009), and the stages adopted were structured as outlined in the following sections.

2.2. Literature review protocol

A literature review study may cover a variety of subjects, including research findings, with varying degrees of completeness. The main components of a literature review are the following. First, it may (or may not) include a detailed search process. Second, it may (or may not) include quality assurance. Third, literature reviews may be conceptual, chronological or thematic (Grant and Booth, 2009). The research protocol for our literature review process was formulated (Dresch et al., 2015; Moher et al., 2009) and can be seen in Table 1. The research protocol formalizes the search strategy adopted, including databases, period of time considered, keywords utilized in the search process and the inclusion and exclusion criteria applied. The search strategy based on the PRISMA protocol included several stages (Fig. 1).

Table 1
Research protocol.

Research protocol element	Description
Planning of the research process	Definition of the issue from the literature lacks (RQ1 and RQ2).
Research databases	Scopus and Web of Science.
Publication type	Peer-reviewed papers published in journals, references and textbooks on PSS and SPSS.
Language	Papers in English.
Data range	1995 (January) to 2022 (January).
Search fields	Title, abstract and keywords of papers in the databases.
Search terms	46 keywords were identified. The combination of keywords and the Boolean operators is detailed in Appendix A.
Inclusion criteria (eligibility)	(i) conceptual papers based on literature reviews and surveys examining PSS and SPSS concepts; (ii) theoretical articles discussing convergences and divergences between PSS and SPSS; (iii) empirical articles examining the transition process in companies to PSS and to SPSS.
Exclusion criteria	(i) paper without a formalized definition to PSS and SPSS concepts; (ii) studies with high quantitative or statistical bias making it challenging to capture theoretical and qualitative insights; (iii) papers lacking methodological rigour; (iv) grey literature and unpublished articles.
Data extraction	The originality of the definition of PSS and SPSS formulated in the paper was the criteria considered for the extraction and selection of the definitions.
Data analysis and synthesis	(i) manually screen the papers and content analysis of the papers; (ii) Natural Language Understanding (NLU) tool based on AI and Neural Networks methods; (iii) analyses and synthesis of information against the literature on PSS and SPSS.

During the first stage of the literature analysis, we completed the planning of the research process, the definition of the issue and the conceptual framework. In the second stage, we identified publications by using a screening process. The keywords, search strategy, period, databases, exclusion and inclusion criteria and the eligibility/coding were also applied in this process. A preliminary analysis of the related literature was performed to operationalise this process, looking for studies focused on the PSS and SPSS domains. This step was relevant to identify a comprehensive set of the essential keywords widely used by academics exploring this domain in previous studies on PSS and SPSS.

Next, the search process was conducted in the scientific databases. The keywords selected were extracted from previous systematic literature review studies carried out on these related research topics (Annarelli et al., 2016; Reim et al., 2015; Tukker, 2015; Lightfoot et al., 2013; Rabetino et al., 2018; Beuren et al., 2013; Meier et al., 2011; Baines et al., 2007, among others). This set of keywords expresses the most frequent terms and acronyms used in the extant literature on PSS and SPSS. The search process was carried out by making paired combinations of the keywords identified with each one of the following keywords: “literature review”, “systematic review”, “state of the art” and “review” (Appendix A). In this case, an illustrative example of a combination performed was the following: ((“Product-service system”) AND (“literature review”)). We decided to use Web of Science and Scopus mainly because of their comprehensive coverage in terms of knowledge. However, since they do not necessarily index the totality of the same journals (Mongeon and Paul-Hus, 2016), Scopus and Web of Science do not work the same way in terms of searching. Thus, in Scopus, the following criteria were used: (i) Search within: “Article title, Abstract and Keywords”; (ii) Subject area: Engineering, Social Sciences, Computer Science, Environmental Science, Economics, Econometrics and Finance, Business, Management and Accounting and Decision Sciences; (iii) Document type: review. In Web of Science, the following criteria were used: (i) Search within: Abstract; Web of Science Core Collection; Editions: All; (ii) Subject area: Engineering Industrial, Business, Engineering Manufacturing, Green Sustainable Science Technology, Environmental Sciences, Management, Engineering Environmental, Operations Research Management Science, Computer Science Information Systems, Environmental Studies, Computer Science Interdisciplinary Applications, Engineering Multidisciplinary, Economics, Mechanical Engineering, Business Finance and Social Science Interdisciplinary; (iii) Document type: review.

The third stage of the search process was carried out using specific screening eligibility criteria. In this stage, given that SPSS is also a common acronymous also widely referred to as the statistical software package, the researchers dedicated special attention. Specifically, during the screening process of the papers by examining the title and abstract of the papers and by examining the subject and internal content of the paper, only those studies related to PSS and SPSS were examined. The search period considered in the search process was between 1990 and 2022 (January). The literature analysis was segmented into two distinct periods: period 1 (1990–2009) and period 2 (2010−2021), to examine the evolution of the definitions over time. Additionally, during the data collection period and exploration of the literature, a snowball process was implemented. Different approaches to identifying relevant literature should preferably be adopted to ensure the best possible coverage of the literature (Jalali and Wohlin, 2012). Hence, backwards snowballing was implemented to select relevant studies proposing original conceptual definitions of PSS and SPSS. Backwards snowballing means using the references selected in the study to identify additional papers to include. As a result, five papers were selected. The usefulness of snowballing is expressed by Wohlin (2014): “In particular, it should be noted that snowballing is particularly useful for extending a systematic literature study, since new studies almost certainly must cite at least one paper among the previously relevant studies, or the systematic study already conducted in the area. Thus, snowballing is by deduction a

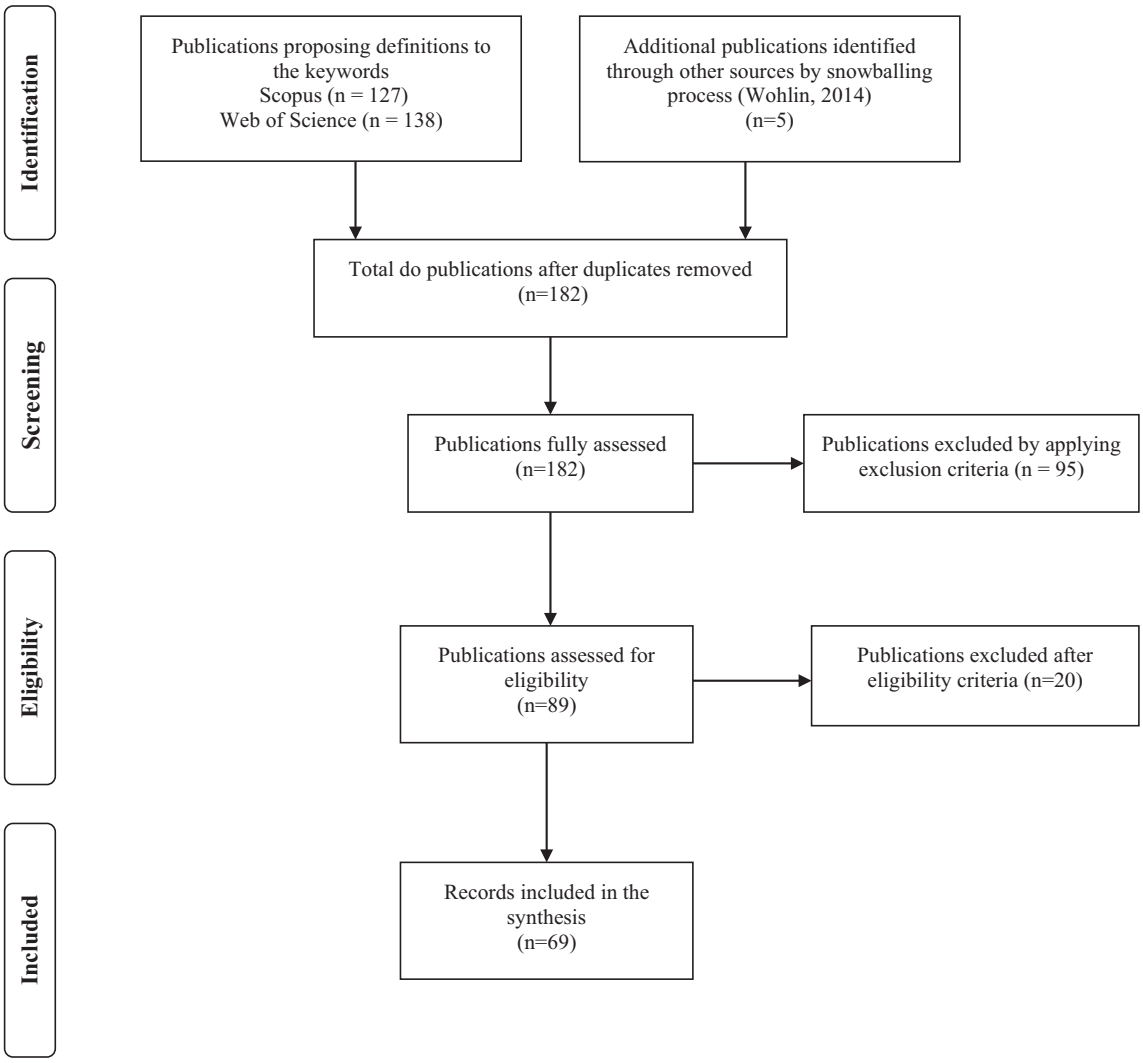

Fig. 1. Flow diagram of literature review.

better approach than a database search for extending systematic literature studies." (Wohlin, 2014, p. 9). For the purpose of exploring the literature in this research theme, the snowball approach enabled us to identify additional relevant articles through the cross-reference analysis of relevant studies on PSS and SPSS. "One of the main advantages of snowballing is that it starts from relevant papers and then uses these to drive the further study. Reference lists are quite easily examined and when combined with the place and context of the reference, it becomes in most cases quite straightforward to identify relevant papers." (Wohlin, 2014, p. 9). The use of snowballing to complement literature reviews is a well-established approach in the extant literature about the theme. Recent studies published in the Environmental Impact Assessment Review journal applied the snowball approach with the same proposal of our study to complement the literature analysed (Blue et al., 2021; Arioli et al., 2020; Kabisch et al., 2015). For example, Blue et al. (2021) adopted snowball during the initial screening of literature based on inclusion criteria. The research developed by Kabisch et al. (2015) added complementary papers that were not part of the original search but were referenced within identified articles. Similarly, in the paper by Arioli et al. (2020), three papers were included in the review based on the snowballing approach.

The inclusion of studies for full analysis followed these eligibility criteria: (i) scientific articles investigating firms' transition process to PSS and SPSS based on empirical analyses; (ii) theoretical scientific articles discussing convergences and divergences between PSS and SPSS; (iii) articles in the English language; (iv) articles based on a literature review methods; (v) peer-reviewed studies (this was an inclusion criterion considered for all previous criteria). The exclusion criteria implemented were: (i) studies with high quantitative or statistical bias making it challenging to capture qualitative insights; and (ii) grey literature.

In the fourth stage of the search process, the final filtering and process analysis were conducted. The data retrieved from each study were used to identify relevant aspects related to the PSS and SPSS trajectory, and the various similarities and differences of the models were noted. Initially, the analysis of the selected studies used the open coding content analysis, which aimed to determine if publications included a discussion about PSS and SPSS methodologies. Duplicate studies and papers filtered by inclusion and exclusion criteria were excluded. In fact, a number of studies were excluded for three principal reasons: (i) they were duplicate studies, (ii) they were from areas not related to PSS or service management fields, such for example, software engineering or computer science and (iii) they exhibited only a weak link with the focus of this research. The research team implemented the following screening process to examine the papers. In the first filter of analysis, during the search process in Scopus and Web of Science databases, we examined the title and the abstract of the papers to verify if the content of the paper directly discussed PSS or SPSS methodologies. As a result, no related papers were disregarded. Next, we carried out a screening in all the

sections of the potential papers to identify if the paper proposed original definition(s) or cited definition(s) from other authors. Third, we examine the definitions indicated in the papers to separate those specifically related to PSS and SPSS. In this stage, the definitions related to other concurrent methodologies were excluded. Fourth, the set of definitions was grouped, and the duplicated definitions were removed. As a result, the final set of definitions related explicitly to PSS and SPSS was obtained for further analysis. During the scrutiny of the literature, the studies mostly cited previous definitions already formalized for PSS and SPSS rather than proposing new or updated conceptual definitions for these approaches. As a result, 69 studies (Appendix B and C) were included and further analysed to address the research questions examined in this paper.

2.3. Data analysis

The primary tool utilized for the data analysis was NLU. NLU is a "system that computes the meaning representation, essentially restricting the discussion to the domain of computational linguistic." (Jusoh and Alfawareh, 2012, p. 432). NLU was applied to analyse the textual content of the conceptual definitions of PSS and SPSS retrieved from the relevant literature. The NLU tools can be comprehended as a collection of Application Programming Interfaces (APIs) that offer automatic text analysis based on algorithms through NLP without human interference. "NLP is a key component in many data science systems that must understand or reason about a text. Common use cases include question answering, paraphrasing or summarizing, sentiment analysis, natural language, BI, language modelling, and disambiguation." (Kocaman and Talby, 2021, p. 1). NLP is defined as a set of computational tools for analyzing and expressing the natural meaning of texts at one or several linguistic levels. NLP is a field of study that examines how computers are used to comprehend and manage natural language texts or speeches in order to perform a required task (Vijayarani et al., 2015; Jusoh and Alfawareh, 2007). Today, NLP is a valuable and sophisticated tool that can be combined with modern technologies like artificial intelligence, machine learning and deep learning to enhance the interpretation and processing of data. NLP enables massive volumes of unstructured data analysis and organization in various applications. As a result, NLP can outperform humans in complex activities that include massive information (Bahja, 2020). Therefore, the specialization of NLP for textual analysis justifies why it is a suitable approach to this study.

To address the research questions of interest, this study uses a combination of qualitative and quantitative analysis provided by NLU to obtain insights into the evolution of PSS and SPPS concepts over time. This complementary approach was employed since the NLU attributes are widely recognised for identifying and characterizing textual content (Abdellatif et al., 2021; Kocaman and Talby, 2021; Flores et al., 2020; Ilmania et al., 2018). NLU adopts NLP techniques and machine learning to automatically analyse the semantic features and extract structured textual information (Abdellatif et al., 2021; Flores et al., 2020).

Specifically, three categories of information were examined using the NLU algorithms in our study: (i) Extraction rules: Entities, Keywords and Concepts; (ii) Classification rules: Sentiment and Hierarchy analysis; (iii) Linguistic analysis: Semantic roles. The data analysis processes were performed using the Watson platform (IBM, 2020). Watson is a cloud-based platform on which it is possible to build cognitive systems that can improve processes, interactions and actions. It works by applying AI and Neural Networks using the software IBM DeepQA and the framework Apache UIMA (Unstructured Information Management Architecture). It implements APIs allowing analysts to programmatically analyse the semantic content of the information (e.g. semantic data, ontologies). Recent studies on the performance comparison of NLU engines have recommended using Watson for content analysis tasks and knowledge extraction due to the reliability of the outcomes (Flores et al., 2020).

The parameter Concept, for instance, recognises the high-level concepts related to the textual information examined. The result of the analysis of the parameter Concept is informed on a scale from 0 to 1, in which 0 means the lower significance of the Concept to the input data, and 1 means it is the highest significance of this concept. For example, the analysis of a text about Deep Learning would likely return to the concept 'Artificial Intelligence', although this word is not directly cited in the text examined. In this case, as a result of the analyses of the definitions of PSS and SPSS, several concepts directly and indirectly related to PSS and SPSS were suggested. Already, the parameter Sentiment analyses the general Sentiment of the text. Sentiment analysis is one of the main important themes in NLP studies since "It identifies and extracts subjective information then classifies them into three following polarities: positive, negative, and neutral (Ilmania et al., 2018).

The parameter Relevance for Keywords applied determines the most important keywords, which are scored by relevance on a scale of 0–1, where 0 indicate that the keyword is not significant and 1 indicate that the keyword is extremely relevant to the text under consideration. Another parameter adopted was the Hierarchy. It categorises terms depending on a hierarchical order or hierarchical levels (Gao et al., 2020). The hierarchical classification algorithms return a hierarchical taxonomy of the content of text analyses in structured levels. The results from Watson consider the open database of a taxonomy of categories called 'IAB Tech Lab 2.0 taxonomy'. This implies that the taxonomies' outcomes follow a pre-determined classification generically utilized by computer scientists and analysts. The outcomes of the hierarchical classification through API used by Watson are presented in up to three category levels (Level 1, Level 2, Level 3). For example, in the content analysis of a text on the automotive industry, a possible result of three levels of hierarchical taxonomy could be the following: Automotive/Auto Body Styles/Sedan. For reasons of reproducibility, scrutiny and future advances to this research domain, it is important to note that the database of definitions used is attached as Appendix D. This ensures that the data sets used in this study are publicly available without restrictions to access. The research findings are then presented in detail in the next section.

3. Findings

Based on the literature review results, a comprehensive set of definitions of PSS and SPSS approaches was selected for the analysis. Initially, the results on the PSS are presented. In the following sections, the findings are analysed in detail.

3.1. Evolution of PSS definitions and scope

Research communities use a collection of terms to describe the new trend of manufacturing companies that integrate product and service (e.g., extended products, servitisation, technical services, product-service system). These terms all indicate the same conceptual idea: a mix of tangible products and intangible services designed to increase the added value for customers. Value creation can be provided through an extended business network involving different stakeholders, some of whom concur to create the services (Marilungo et al., 2016). The evolution of the main definitions of PSS over time, as proposed by relevant authors in the field, could then be identified and organized (Appendix B).

From a qualitative analysis of this set of definitions, the following conclusions emerged: (i) first, not all definitions since the foundation of PSS literature cover the TBL dimensions of the sustainability of PSS; (ii) comprehensive key factors to an adequate PSS provision to the market, such as the idea of an integrated system, networks of "players", supporting infrastructure, are not present in all definitions; (iii) on the other hand, the idea of fulfilling customer needs and the business perspective is frequently cited in the definitions.

We also developed a cloud of words (http://tagcrowd.com) to comprehend the frequencies of words cited in the two periods considered (Figs. 2 and 3).

Fig. 2. Frequent words cited in PSS definitions for the first period of analysis (1990–2009).

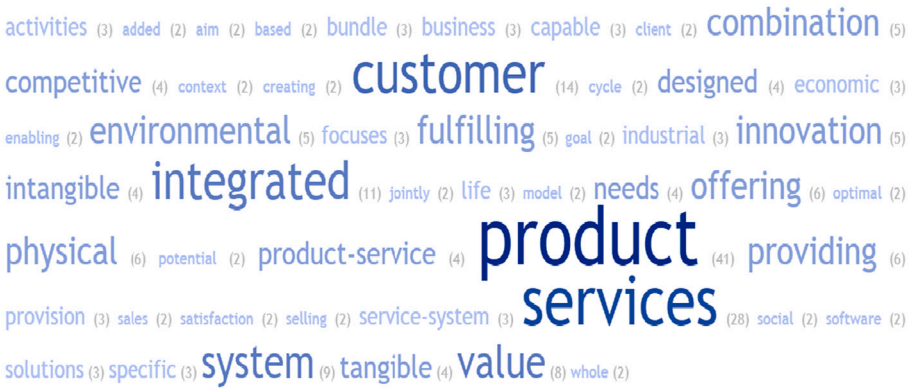

Fig. 3. Frequent words cited in PSS definitions for the second period of analysis (2010−2021).

The results show that the words 'products', 'service-system', 'services', 'customer', and 'system' are the most frequent definitions in both periods.

3.2. Evolution of SPSS definitions and scope

It was found that despite SPSS having been apparently formalized clearly for the first time in the 2000s (Maxwell and van der Vorst, 2003), only recently, from 2014 onwards, were different conceptualisations proposed to define the real meaning (Appendix C). Moreover, it was possible to note that, similarly to PSS, the research context of SPSS was mainly large companies, neglecting, for example, the role of SMEs.

In contrast to the previous set of PSS definitions, the outcomes confirm that more recent definitions of SPSS more explicitly consider the environmental aspect and the sustainable perspective and concept (de Jesus Pacheco et al., 2019; Tseng et al., 2019a, 2019b; Kuo et al., 2019; Wang et al., 2020; Liu et al. (2021); Negash et al., 2021). It was observed that the terms 'product', 'services', 'environmental' and 'sustainable' are the most frequent words in SPSS definitions in both periods (Figs. 4 and 5).

Overall, by comparing the two results regarding PSS and SPSS, it was observed that the emphasis on the sustainability challenges (e.g., sustainability, environmental) is more explicit in SPSS definitions than in PSS. The following section presents the results obtained from applying the NLU algorithms.

3.3. Results of natural language understanding algorithms

In order to understand the synergies and divergences between PSS and SPSS to deliver TBL solutions and to comprehend how PSS and SPSS concepts have advanced, we implemented several NLU algorithms to examine the conceptual definitions extracted from the structured

Fig. 4. Frequent words cited in SPSS definitions for the first period of analysis (1990–2009).

Fig. 5. Frequent words cited in SPSS definitions for the second period of analysis (2010–2021).

literature review. This section presents the outcomes obtained in the three categories of information examined with the NLU algorithms: (i) Extraction rules: Entities, Keywords and Concepts; (ii) Classification rules: Sentiment and Hierarchy analyses; (iii) Linguistic analysis: Semantic roles.

The results were organized by comparing the conceptual definitions of the literature between two periods: the first period of analysis (1990–2009) versus the second period of analysis (2010–2021). The following reasons justify the choice of these periods. The first reason is that the pioneering research on PSS started to be published in the 90s. The second motive is because the literature indicates an increasing number of studies on PSS and SPSS from 2010 and onwards (Reim et al., 2015; Tukker, 2015; Vezzoli et al., 2015; Beuren et al., 2013). Third, a number of impactful research projects and studies specifically on SPSS were observed from 2010 (Vezzoli et al., 2015; Mylan, 2015). The knowledge generated by these projects can potentially add new developments to the PSS and SPSS fields. The following sections present the results of the parameters analysed.

3.3.1. Results of concept analyses

The first parameter analysed with NLU algorithms in Watson was Concept. This parameter recognises the high-level concepts related to the original definitions of PSS and SPSS. The scale of the Concept parameter varies from 0 to 1, in which 0 means the lower significance of the Concept to the input data, and 1 means it is the highest significance. In this case, and as a result of this analysis, several Concepts directly and indirectly related to PSS and SPSS were suggested. The list of concepts returned and the highest indexes of results are presented in Tables 2 and 3.

As can be seen from Table 2, the results classified five main Concepts (triple bottom line, sustainability, economics, sociology and social) that are clearly associated with the TBL dimensions in SPSS definitions. A similar finding was observed in the second period examined (Table 3), in which seven primary Concepts are associated with the TBL dimensions (sustainability, sustainable business, triple bottom line, economy, natural environment, sustainable living, and ecological economics). On the other hand, it can be seen from the data in Tables 2 and 3 that seven Concepts are associated with the business perspective in PSS.

Table 2
Ranking of Concepts index results for the first period of analysis (1990–2009).

Concepts for PSS (First 10 Concepts listed)	Index	Concepts for SPSS (First 10 Concepts listed)	Index
Marketing*	0.97	Triple bottom line**	0.99
Customer*	0.57	Sustainability**	0.93
Service system	0.54	Economics**	0.79
Product management	0.53	Marketing*	0.767
Strategic management*	0.50	Value added*	0.75
Consultative selling*	0.50	Product service system	0.74
Customer service*	0.45	Sociology**	0.52
Management*	0.45	Maxima and minima	0.52
Business*	0.42	Social**	0.51
Design	0.42	Customer service*	0.50

* Concepts more directly associated with the business perspective.
** Concepts more directly associated with the TBL dimensions.

Table 3
Ranking of Concepts index results for the second period of analysis (2010–2021).

Concepts for PSS (First 10 Concepts listed)	Index	Concepts for SPSS (First 10 Concepts listed)	Index
Product service system	0.99	Sustainability**	0.99
Marketing*	0.88	Customer*	0.62
Value added*	0.78	Sustainable business**	0.52
Product management	0.71	Triple bottom line**	0.50
Consultative selling*	0.57	Customer service*	0.46
Capital accumulation*	0.56	Dimension	0.45
Intermediate consumption	0.54	Natural environment**	0.45
Value*	0.53	Economy**	0.43
Sustainability**	0.52	Sustainable living**	0.41
Product life cycle management	0.51	Ecological economics**	0.40

* Concepts more directly associated with the business perspective.
** Concepts more directly associated with the TBL dimensions.

Interestingly, the outcomes observed in the second period indicate that the Concept 'sustainability' is occupying a dominant position, approximately the maximum score (0.99) and even with a significant difference concerning the second most relevant Concept (customer, score 0.62). Lastly, regarding the PSS analysis, the findings (Table 3) indicated only one Concept associated with the TBL view (sustainability, score 0.52). Thus, these preliminary results support the idea that the difference between the PSS and SPSS concepts may be considered relevant in terms of their association with the TBL perspective of sustainability.

3.3.2. Results of relevance for keywords analysis

The second parameter applied in the content analysis of the PSS and SPSS definitions was the index of Relevance for Keywords. This parameter was used to discover interrelations, new knowledge and the main keywords found in the set of definitions on PSS and SPSS. The ranking results based on selecting the ten main keywords with the highest index of parameter Relevance can be seen from Tables 4 and 5.

The findings show that differences in the results in terms of TBL orientation are salient to this parameter. A closer inspection of Table 4 indicates that the TBL orientation is more salient in the SPSS model. Results show that seven of the keywords extracted are associated with the TBL dimensions. On the other hand, the results of the PSS analysis show four Keywords associated with the business perspective (user's needs, customer needs, centre of the business design, and traditional business models). The same comparative analysis was performed for the

Table 4
Index of Relevance of Keywords results for the first period of analysis (1990–2009).

Keywords for PSS (First 10 Keywords listed)	Index of relevance	Keywords for SPSS (First 10 Keywords listed)	Index of relevance
System of products	0.94	Eco-efficient services**	0.91
Predesigned system of products	0.79	Systems of products	0.89
New interpretation of the product value chain	0.69	Environmental impact**	0.73
Defined user period	0.64	Sustainable product**	0.73
User's needs*	0.63	Alternative product-service mix	0.73
Separate products	0.63	Social aspects**	0.68
Customer needs*	0.63	Economic prosperity**	0.65
Services	0.58	Environmental protection**	0.62
Centre of the business design*	0.57	Eco-efficient service**	0.60
Traditional business models*	0.56	Service development	0.60

* Keywords more directly associated with the business perspective.
** Keywords more directly associated with the TBL dimensions.

Table 5
Index of Relevance of Keywords results for the second period of analysis (2010–2021).

Keywords for PSS (First 10 Keywords listed)	Index of relevance	Keywords for SPSS (First 10 Keywords listed)	Index of relevance
Greater integration of products	0.89	Product-service system design	0.97
Product service-system design activity	0.76	Sustainable product**	0.84
Mere product sales*	0.72	Design of the system of products	0.77
Integrated bundle of hardware	0.66	Particular customer demand*	0.66
Integrated offering of tangible products	0.63	Satisfactory value*	0.64
Services*	0.59	Service systems*	0.64
Product life cycle	0.59	Product-service solutions	0.63
Right combination of products	0.58	Efficient resource utilisation**	0.61
Service shares*	0.57	Satisfaction system*	0.58
Offering firm*	0.57	Customer needs*	0.58

* Keywords more directly associated with the business perspective.
** Keywords more directly associated with the TBL dimensions.

period between 2010 and 2021 (Table 5).

The results in Table 5 show that two keywords are more clearly associated with the TBL dimensions (efficient resource utilisation and sustainable product) for SPSS. Furthermore, the term 'design' appears to be relevant to the concept of SPSS in the second period. This result is quite revealing, considering that the results from the first period (Table 4) do not indicate the focus on the design activities of SPSS models. Also, as can be seen, the seven Keywords denote a business or an economic perspective of PSS.

Therefore, from these comparative analysis results, it is possible to observe that the knowledge generated by the NLU algorithms classified in both periods of analysis suggests that the SPSS definitions are more clearly related to the TBL dimensions. On the other hand, the same pattern of results is not evidenced when examining the PSS definitions in both periods.

3.3.3. Results of sentiment analysis

The third parameter analysed in our study was the parameter Sentiment. This parameter indicated the overall sentiment-level of content detected in the text by disclosing the general tone of the content of the text analysed. To perform the analyses, the algorithms consider the Sentiment of a set of primary keywords contained in the definitions examined. The result of this analysis is represented by the keywords' Sentiment scores.

The Sentiment score for the concept being analysed can have the polarity positive, neutral or negative. In this case, the outcomes from the API can return a score ranging from −1 (very negative) up to 1 (very positive). Negative scores indicate a negative tone of Sentiment of the content of the text, while positive scores indicate positive Sentiment. Tables 6 and 7 below present the summary of the ten first results with the highest Sentiment scores.

The findings from both periods provide important results. First, the Sentiment scores for both PSS and SPSS have a positive polarity for both periods examined. This result implies that the keywords mentioned are important and positively influence the understanding of PSS and SPSS models. Second, the results regarding SPSS definitions indicated a set of keywords more clearly related to TBL dimensions in the first period (economic prosperity, environmental protection, sustainable product and sustainable way) and in the second period (efficient resource utilisation, type of sustainable business model and social aspects). Third, it is interesting to note that in the PSS results, in both periods, all the keywords extracted are related to business or marketing (e.g., marketable mix of products, centre of the business design, physical products, pure service system). These findings corroborate the results indicated by the previous parameters, suggesting a dominant association of SPSS with the TBL dimensions.

3.3.4. Results of the semantic role analyses

The Semantic Roles assigned labels to the content of the PSS and SPSS definitions found in the texts. The resulting key Semantic Roles are important when defining relevant roles, meaning of key relations and conceptual assumptions involving PSS and SPSS. Usually, the semantic roles generated by NLU are presented following the logic subject-action-result (object). Tables 8 and 9 provide the results obtained from the prominent Semantic Roles analyses for the two considered periods.

The findings obtained from the Semantic Roles demonstrated a similar pattern of results. First, the results of the first and second periods clarify fundamental relations and conceptual premises that link the TBL perspective with the SPSS concept. Second, no association was found between PSS and sustainability in the first period examined. Third, interestingly, when examining the second period, the results indicate a more explicit association between SPSS and the TBL view by unveiling conceptual premises to the five Semantic Roles identified. These findings

Table 6
Sentiment analysis results for the first period of analysis (1990–2009).

Keywords Sentiment for PSS	Sentiment scores (+)	Keywords Sentiment for SPSS	Sentiment scores (+)
Marketable mix of products*	0.98	Pragmatic industry support	0.98
Predesigned system of products	0.97	Types of offerings	0.98
New interpretation of the products	0.97	Service development approach	0.98
Separate products	0.97	Market*	0.97
Centre of the business design*	0.95	Economic prosperity**	0.97
Property rights	0.94	Environmental protection**	0.97
Service provider*	0.94	Sustainable product**	0.97
Pure product system	0.94	Service development*	0.96
Product provider	0.94	Process	0.96
System of products	0.89	Sustainable way**	0.96

* Keywords more directly associated with the business perspective.
** Keywords more directly associated with the TBL dimensions.

Table 7
Sentiment analysis results for the second period of analysis (2010–2021).

Keywords Sentiment for PSS	Sentiment scores (+)	Top 10 keywords for SPSS	Sentiment scores (+)
Product life cycle	0.98	Stakeholders of the value production system	0.98
Integrated offering of tangible products	0.94	Particular customer demand*	0.97
Industrial product-service systems	0.93	Efficient resource utilisation**	0.97
Physical products	0.93	Type of sustainable business model**	0.97
Economic growth**	0.92	Integrated mix of products	0.97
Greater integration of products	0.92	Social aspects**	0.97
Mere product sales*	0.92	Offer model	0.97
Business success*	0.91	Product-service system design	0.95
Maximum customer value*	0.91	Design of the system of products	0.95
Goals of product service-system	0.91	Satisfaction system	0.95

* Keywords more directly associated with the business perspective.
** Keywords more directly associated with the TBL dimensions.

corroborate the previous results observed regarding the prominence of TBL elements in SPSS.

3.3.5. Results of entities analyses

NLU algorithms allow extracting from the textual analyses some terms which represent distinct entities that are more informative and also have a specific context to the content examined. In practice, these named entities represent real-world components or stakeholders (e.g., organizations, people, places) that are usually attributed to the PSS and SPSS concepts.

Regarding the results of the Entities analyses, for the first period examined, this study found that generally: (i) the most representative entity linked with the PSS definitions (confidence 0.98) is 'product service systems' linked to the entity 'organization'; (ii) the representative entity linked with the SPSS definitions (confidence 0.86) is the name 'influencing' linked to the entity 'organization'; in addition, the entity 'organization' was extracted with less value of confidence to the following names: 'product service systems' (confidence 0.44), 'triple bottom line' (confidence 0.33) and 'sustainable product and service development' (confidence 0.33).

The results of the second period of the analysis indicate that: (i) the most representative entity linked with the PSS is the name 'temporary proprietor' linked to the entity 'JobTitle' (confidence 0.61), which should be interpreted in the context of PSS where the ownership of the servitized solution remains with the provider, and consequently, the role of the user as a temporary proprietor of the solution. Finally, the results do not indicate any entity extracted from the content analysis of SPSS definitions.

Table 8
Results of the Semantic Roles analyses for the first period of analysis (1990–2009).

Main semantic roles for PSS			Main semantic roles for SPSS		
Subject	Action	Object	Subject	Action	Object
A product service-system	Is	A system of products and services	Eco-efficient services	Are	Systems of products
A product service-system	Supporting	Infrastructure that continuously strives to be competitive	An eco-efficient service	Is	One which reduces the environmental impact of customer activities per unit of output
Product service-system	Is	A predesigned system of products, services	Influencing customer activities	To become	More eco-efficient
Product service-system	Supporting	Networks and infrastructure that is designed to be competitive	Sustainable product and service development	Making	Products and/or services
Utility	Delivering	To consumers that have a smaller environmental impact than separate products and services that fulfil the same function	This	Achieving	An optimum balance between environmental protection, social equity, and economic prosperity

Table 9
Results of the Semantic Roles analyses for the second period of analysis (2010–2021).

PSS			SPSS		
Subject	Action	Object	Subject	Action	Object
Product service-system	Is	An innovation strategy	Sustainable product-service system	Is	An approach to achieve benefits in the three dimensions of sustainability
Business success and economic growth	To de-couple	from mere Product sales		Helps	To embed environmental and social aspects into strategic business goals and processes while increasing competitive advantage
A product	Viewing	As an isolated entity	The economic and competitive interest of the providers	Seeks	Environmentally and socio-ethically beneficial new solutions
The product service-system design activity	Creating	The right combination of products and services	Sustainable product-service systems	Means	That product-service solutions should generate satisfactory value for customers and fulfil the sustainability requirements at the same time
The product service-system design activity	To aid	The customer	A unit of satisfaction	Based	On the design of innovative interactions of the stakeholders

3.3.6. Results of hierarchy analyses

The last parameter analysed with the NLU algorithms was Hierarchy. The result of the Hierarchy expresses a logical ordination that might be used to describe the content of the definitions of PSS and SPSS analysed. The results of the hierarchical levels are presented in up to three levels; please see Tables 10 and 11.

The outcomes identified for the hierarchical levels of PSS and SPSS indicate similar patterns of taxonomies for the two periods of analysis. The hierarchical classification results pointed to the standard three-level hierarchy 'business and finance/industries/information services industry' for PSS (first period: 0.92; second period: 0.91) with the highest scores. Regarding SPSS, the term environmental appears in the three-level hierarchy 'business and finance/industries/environmental services industry' (first period: 0.93; second period: 0.86) with the highest scores. Comparatively, these highest scores suggest a close association with business and economic content to both PSS and SPSS.

Collectively, the integrative analyses of the results obtained with the information extracted from the six parameters of NLU considered indicate a more salient association between the TBL dimensions with SPSS than in PSS. This is the most direct finding emerging from this study. In short, these findings reinforce the hypothesis that SPSS is an approach in which the environmental and social aspects are more explicit in the literature.

4. Discussion

4.1. Synthesis of findings

This research aimed to examine how PSS and SPSS have advanced towards TBL solutions and identify the main synergies and divergences between PSS and SPSS to deliver TBL solutions to society. The consolidated research results obtained by implementing the NLU techniques are presented in Table 12.

These results provide additional evidence for the hypothesis that a more salient association exists between the TBL dimensions and SPSS than between TBS dimensions and PSS. These findings obtained have significant implications that help to answer the research questions of this article that attempt to understand what the main synergies and divergences are between PSS and SPSS regarding delivering TBL solutions (RQ 1) and how the PSS and SPSS concepts have advanced in the literature in terms of the TBL perspective (RQ 2). Although it is possible to affirm that the research examining the main synergies, divergences and how PSS and SPSS have advanced to generate TBL solutions is still in its first stages of development, our findings offer distinct insights to this debate by developing an evolutional analysis applying robust NLU techniques based on AI and Neural Networks.

Hence, findings complement previous related studies (Negash et al., 2021; Tseng et al., 2019a, 2019b; Rabetino et al., 2018; Annarelli et al., 2016), providing additional evidence that corroborates the hypothesis that a more salient association exists between the TBL dimensions and SPSS than the PSS models. This paper represents a research effort to build a foundation for the systematic development of the research framework that examines the real benefits of PSS and SPSS models in society. In the next section, the implications of the results are discussed against the literature in the area. The chain of evidence from research communities in the area is included in the discussions. The discussions examine the TBL impact of PSS and SPSS models and the main challenges for exploring the potential of SPSS.

Table 10
Hierarchy analyses for the first period of analysis (1990–2009).

Hierarchical levels for the PSS definitions	Score	Hierarchical levels for the SPSS definitions	Score
Business and finance/ industries/information services industry	0.92	Business and finance/ industries/environmental services industry	0.93
Technology & computing/ computing/information and network security	0.87	Business and finance/ industries/information services industry	0.79
Business and finance/business/ sales	0.85	Business and finance/business	0.75

Table 11
Hierarchy analyses for the second period of analysis (2010–2021).

Hierarchical levels for the PSS definitions	Score	Hierarchical levels for the SPSS definitions	Score
Business and finance/ industries/information services industry	0.91	Business and finance/ industries/environmental services industry	0.86
Business and finance/business/ sales	0.85	Business and finance/business	0.80
Business and finance/ industries/environmental services industry	0.82	Business and finance/economy	0.78

4.2. Triple bottom line impact of PSS and SPSS models

Some scholars have observed that PSS implementation might indeed result in negative impacts on environmental questions, generating only financial advantages (Barquet et al., 2016b; Tukker, 2015; Vasantha et al., 2012; Halme et al., 2006). This occurs because most empirical PSS implementations in companies fail to balance the social aspects and, to a certain extent, the environmental aspects. This limitation is problematic because the definitions of the PSS underscore sustainable development (Doualle et al., 2016). However, often there is an environmental impact, such as in systems where products are borrowed and returned, transportation costs arise (including the resultant use of fuel and pollution emissions) over the life of the product. In some specific cases, the total fuel cost and environmental impact may make the system non-viable over the long term (Beuren et al., 2013).

While the literature diverges on the potential of TBL in PSS (Negash et al., 2021; Tseng et al., 2019a, 2019b), other academics maintain that it is an essential characteristic of PSS models (Wang et al., 2011; Cook et al., 2006). These authors believe that PSS is a way of dealing with unsustainable consumption patterns and reducing consumption through alternative scenarios of product use, including closing material cycles and increasing dematerialisation to improve resource and functional efficiency of each element (Barquet et al., 2016a; Wang et al., 2011; Mont, 2004). In addition, PSS might still help through the dematerialisation and creation of sustainable products by decreasing waste and the consumption of raw materials (Beuren et al., 2013; Wang et al., 2011; Halme et al., 2006).

PSS models might be more efficient from an environmental perspective thanks to more resource productivity, conscious product usage and a circular manufacturing process (Kucukvar, 2021; Tseng et al., 2019a, 2019b; Marilungo et al., 2016). However, this potential requires the business model being appropriately and correctly implemented and verified (Boucher et al., 2016).

The most significant potential for sustainability improvements from PSS can be attained from increased/improved resource utilisation and innovations, which can likely make the production or delivery process more sustainable (Reim et al., 2015). Use-oriented PSS potentially intensifies the use of material products and hence could reduce the need for materials, but a possible drawback is that this could prompt less careful use, leading to quicker wear and tear. Result-oriented PSS has the highest potential and provides an incentive to reduce material costs but requires the most radical change in the business model compared with product sales. This would likely hamper their broad implementation and hence real contribution to resource-efficiency and circularity (Tukker, 2015).

However, despite expected benefits, the more general challenge for the deployment of PSS models is the ability to manage the overall

Table 12
Summary of NLU findings.

First period of analysis (1990–2009)			Second period of analysis (2010–2021)	
Parameter	PSS	SPSS	PSS	SPSS
Concepts	No Concept clearly associated with the TBL dimensions (social and environmental) was extracted	Five Concepts clearly associated with the TBL dimensions were extracted	One Concept clearly associated with the TBL dimensions view was extracted	Seven Concepts clearly associated with the TBL dimensions were extracted
Relevance for Keywords	No Keyword clearly associated with the TBL dimensions (social and environmental) was extracted	Seven Keywords clearly associated with the TBL view (social and environmental) were extracted	No Keyword clearly associated with the TBL dimensions (social and environmental) was extracted	Two Keywords clearly associated with the TBL dimensions (social and environmental) were extracted
Sentiment	Polarity is positive for all keywords. All the keywords have a business/marketing orientation	Polarity is positive for all keywords. Four keywords associated with the TBL view were extracted	Polarity is positive for all keywords and for keywords with a business and marketing orientation	Polarity is positive for all keywords. Three keywords associated with the TBL dimensions (social and environmental) were extracted
Semantic Roles	No Semantic Role associated with the TBL view were extracted	Three Semantic Roles associated with the TBL dimensions were extracted	Three Semantic Roles associated with the TBL dimensions were extracted	Five Semantic Roles associated with the TBL dimensions were extracted
Entities	'product service systems' linked to the entity 'organization'	'influencing' linked to the entity 'organization'	'temporary proprietor' linked to the entity 'JobTitle' (the role of the user as a temporary proprietor of PSS)	No entity was extracted
Hierarchy	business and finance/industries/information services industry		business and finance/industries/environmental services industry	

transformation of business models to ensure their convergence towards higher sustainability (Boucher et al., 2016). This is because PSS proposals that are not carefully developed run the risk that the environmental potential will be offset by less careful behaviour of the customers, which is called 'rebound effects' (Tukker, 2015; Reim et al., 2015). Even when well-designed, it has been observed that some PSS changes could generate unwanted side effects (i.e., rebound effects) (Vezzoli et al., 2014; Tukker, 2015).

Therefore, it is essential to recognise that not all shifts to PSS result in effective environmental benefits. PSS may need to be specifically designed, developed and delivered to be highly eco-efficient. Studies suggest that companies should actively strive to optimise their use of resources and design their PSS carefully to be more sustainable and to avoid undesirable rebound effects (Tukker, 2004; Vezzoli et al., 2014; Tukker and Tischner, 2006a).

Corroborating these statements, literature shows that the focus on PSS is frequently mentioned, but limited insights or support is given to achieving sustainability in practical implementations (Vasantha et al., 2015, 2012). Hence, pragmatic tactics, artefacts and guidelines need to be created to help practitioners and firms towards more sustainable offers. Findings also indicate that the central issue for future contributions in the PSS field is to look across borders and integrate results obtained from other approaches and research communities (Cook et al., 2006). Collaboration between researchers and practitioners should be widely emphasised to enhance the industrial applicability of these models. This collaboration can be achieved in practice by taking into account the challenges based on two dimensions – ontology and models – for the representation of PSS (Vasantha et al., 2012).

In short, it has been verified that there has been a revival in interest in PSS for environmental reasons due to the recent interest in resource-efficiency among important actors in civil society, business and government (Tukker, 2015). Nevertheless, the PSS efficiency still needs to be defined and accepted across the PSS research community (Rabetino et al., 2018; Lightfoot et al., 2013) to achieve further effective diffusion within the enterprises. Overall, it is possible to conclude that a more dedicated socio-technical approach to the problem is urgent and necessary, considering all the above limitations of PSS in achieving the sustainability demands of an economy based on the mutual integration of products with services (Vasantha et al., 2015; Mylan, 2015; Ceschin, 2014, 2013).

This socio-technical perspective to approach these problems must be able to overcome the traditional business perspective of value creation and move to an effective holistic and TBL orientation within and across the different business sectors. Recently, relevant studies (Vezzoli et al., 2015) promoted the term SPSS instead of simply PSS models. They thus highlight that SPSS is effectively a win-win proposition: environmentally friendly and socio-ethically correct while also economically sustainable. In summary, the literature supports the idea that the transition to SPSS is a promising approach to addressing the sustainable development' challenges.

In sum, our findings indicated that, on the one hand, the PSS can be considered an approach more focused on business dominant-logic, customer needs and system perspectives of product-service oriented offers. On the other hand, the SPSS approach emphasises the eco-efficiency and a TBL perspective with more clarity. This implies that SPSS can deliver social well-being and economic prosperity, addressing some of the urgent environmental challenges that have challenged the organizations and society as a whole. These assumptions are supported by the following set of outcomes observed in our research. First, these findings are based on the content analyses of the evolution of the definitions of PSS and SPSS available in the extant literature. Second, there is nowadays a preeminent need to redefine the current consumption and production patterns to not compromise the resources available on the planet. Third, there are pieces of empirical evidence in the literature discussing the low effectiveness and practical diffusion of sustainability dimensions (mainly the social and environmental dimensions) in traditional PSS models (Negash et al., 2021; Tseng et al., 2019a, 2019b; Annarelli et al., 2016).

4.3. Main challenges for exploring the potential of SPSS

The SPSS business model is an approach "to achieve benefits in the three dimensions of sustainability" (Barquet et al., 2016b, p. 436). Furthermore, "SPSS is a relatively recent business model that combines tangible products and intangible services to satisfy customer demand. It may be defined as firms integrating products with services to systematically provide functions for replacing tangible products. This type of model is based on interactions between the stakeholders of the triple bottom line, economy, society, and environment, to improve the sustainability of supply chain management". (Kuo et al., 2019; p. 385). Therefore, this research stream takes a different approach to traditional PSS statements and definitions and advocates that SPSS models should be intrinsically embedded in a TBL (economic, social and environmental) perspective of sustainability.

According to Vezzoli et al. (2015), the SPSS models provide higher customer satisfaction and have a significant advantage when it comes to the three dimensions of sustainability. From an economic viewpoint, SPSSs can create new market potentials, higher profit margins and contribute to higher productivity by reducing investment costs through the business life cycle and reducing operating costs for the final users

(Marilungo et al., 2016).

Moreover, the diffusion of SPSS in the market is highly dependent on and sensitive to the culture in which it will be used. Thus, the success of an SPSS offer in the market will depend on the cultural aspects and consumer behaviour in various regions. For example, consumers in certain parts of the world are more likely to accept PSS and SPSS than those from other regions of the world. Therefore, consideration of the cultural conditions is necessary for successful SPSS implementation, and a company should first verify that the right conditions are in place (Doualle et al., 2016). This aspect is also valid for the implementation of PSS business models in practice.

Aligned with these previous propositions, Wong (2004) recognised that SPSSs have been more accepted in communal societies like Scandinavia and other countries in Europe, such as the Netherlands and Switzerland, than in many other countries that do not have this type of social consciousness (Vezzoli et al., 2015; Wong, 2004). Notoriously, these regions are examples of well-developed regions recognised by favourable social and cultural aspects. Significant barriers to SPSS diffusion are often related to user acceptance and adoption of these novel systems (Vezzoli et al., 2015; Chou et al., 2015).

This phenomenon of users being hesitant may be explained by several aspects, including current habits, how the service provider is perceived, as well as by financial reasons or other empirically documented factors that make users feel unsure (Vezzoli et al., 2015). Furthermore, another reason for the limited diffusion of SPSS offers is that it will never be easy for a provider to overcome the perception that he is putting his consumer in a relatively dependent position or influencing, or even prescribing, how consumers should behave (Tukker, 2004).

Overall, the following major conclusions can be drawn from the present study:

First, it is possible that keeping the social sustainability perspective explicitly in mind when assessing the added value of eco-efficient services to consumers would perhaps allow better scrutiny of issues that are relevant to the decision-making (Halme et al., 2006). To sum up, our results are consistent with those of recent studies discussing the real TBL impact of PSS offers in the market. This study also corroborates the literature in which the environmental and social benefits, as well as the genuine PSS design and implementation, have been recognised only as future research ideas (Annarelli et al., 2016).

Second, we found that the knowledge and empirical evidence of both PSS and SPSS topics demonstrate that the TBL perspective of Product-Service Systems is still not widely comprehended and accepted by the different research communities in the services domain (Annarelli et al., 2016; Vasantha et al., 2012; Cook et al., 2006). Our findings also support the need for more decision-making methodologies to assist developers in producing sustainable PSS solutions (Doualle et al., 2020).

Third, the absence of an effective TBL and socio-technical orientation and aspects addressing the complexities of the social dimension might be one of the primary reasons that explain the low practical diffusion of SPSS business models in enterprises and across sectors until the moment.

Taken together, the evidence from this study suggests that SPSS may be considered a more advanced approach in terms of environmental and social perspectives when compared with the traditional PSS, which is more oriented towards business and service system perspectives. The following section describes the main conclusions achieved and future research opportunities in this area.

5. Conclusions

The aim of the present research was (i) to examine how PSS and SPSS concepts have advanced over time towards TBL solutions in society and (ii) to examine the main synergies and divergences between PSS and SPSS methodologies to deliver TBL solutions to society. A detailed analysis of the evolution of the conceptual definitions of PSS and SPSS approaches over time was thus performed to clarify the discussion.

One of the more significant findings that emerged from this study was that the SPSS might be considered a more advanced approach to deal with the environmental and social perspective of sustainability that the traditional PSS model. The integrative results of this study indicated that the SPSS is an emerging and promising approach in which the environmental and social dimensions are more salient than in the traditional PSS models. Moreover, this study can be considered a pioneering study employing robust methods such as NLU tools based on AI and Neural Networks for conceptuallty comparing both approaches.

The findings from this paper make contributions to the current literature. First, we have exposed the limitations of PSS and reinforced the controversy regarding its real sustainable impact on firms and society. Second, the findings of this work extend the current theoretical framework on PSS and SPSS to unlock the present and future challenges in a service-oriented economy. Third, the outcomes can provide some implications for both academia and practice in the field of PSS. In this regard, this article extends the current knowledge on PSS and SPSS approaches, guiding the scientific and business communities interested in unlocking challenges regarding the diffusion of effective and sustainable business models into society. In conclusion, this study stimulates the discussion to advance the understanding of PSS and SPSS models in terms of sustainability.

5.1. Future research agenda

A foundation for future research has been established through this paper. Firstly, we suggest that future lines of research could explore more the current stage of implementation of the SPSS models and their limits and contingency aspects for successful infusion in micro-, small and large firms. Moreover, additional research is required on PSS evaluation to determine its impact on sustainability in a holistic view. Recently it was advocated that PSS is not the sustainability panacea some may think it is. In fact, the success of PSS not only relies on a robust design model but also on its effective operation and management. Therefore, future research efforts should explore and integrate into PSS and within new SPSS propositions the synergies of other correlated research fields (e.g., Design, ICT tools, Operations Management, among others). We believe that these research avenues would foster the effective diffusion of SPSS business models embedded in a true TBL perspective.

CRediT authorship contribution statement

Diego Augusto de Jesus Pacheco: Conceptualization, Methodology, Investigation, Data curation, Software, Writing – original draft, Writing – review & editing, Project administration. **Carla Schwengber ten Caten:** Conceptualization, Supervision. **Carlos Fernando Jung:** Conceptualization, Supervision. **Isaac Pergher:** Writing – review & editing, Data curation. **Julian David Hunt:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Scopus:

(i) *Search within:* "Article title, Abstract and Keywords".
(ii) *Subject area:* Engineering, Social Sciences, Computer Science, Environmental Science, Economics, Econometrics and Finance, Business, Management and Accounting and Decision Sciences.
(iii) *Document type:* review.

Web of Science:

(i) *Search within:* "Abstract" in Web of Science Core Collection; Editions: All.
(ii) *Subject area:* Engineering Industrial, Business, Engineering Manufacturing, Green Sustainable Science Technology, Environmental Sciences, Management, Engineering Environmental, Operations Research Management Science, Computer Science Information Systems, Environmental Studies, Computer Science Interdisciplinary Applications, Engineering Multidisciplinary, Economics, Mechanical Engineering, Business Financeand Social Science Interdisciplinary.
(iii) *Document type:* review.

Table A1
Search process and keywords combination.

Set of keywords 1	Set of keywords 2
Product-service system	
Sustainable product-service system	
Product-service	
Servitisation	"literature review"
Servitization	"state of the art"
Sustainable service	"systematic review"
Industrial product service system	review
Service engineering	
PSS	
IPSS	
SPSS	
Service-dominant logic	
Servicification	
Functional product	
Product service engineering	
Product service offering	
Functional sales	
Functional economy	
Service-based products	
Service-based business	
Service providing	
Sustainability contribution	
Dematerialisation	
Leasing	
Service infusion	
Product-to-service	
Service operation	
Product-related services	
Service integration	
Value bundle	
Covalent product	
Integrated solutions	
Service science	
Service economy	
Servicification post mass production paradigm	
Post mass production paradigm	
Service-oriented	
Integrated solutions	
Product bundling	
Hybrid offerings	
Hybrid product	
Hybrid service	
Hybrid value	
Hybrid bundle	
Sharing economy	
Shared economy	
Circular economy	

Appendix B

Table B1
Evolution of main PSS definitions.

Year	PSS definitions	Source
1993	In the Service Economy, the real issue - regarding economic value - appears to be the maximisation of the combined utilisation of products and services during their life time, an operation which takes into account a series of costs prior to, during, and after production.	Giarini and Stahel (1993)
1999	Delivering a great product is not enough to gain a customer's allegiance. You have to deliver a combination of services that minimises the overall costs associated with owning and using the product.	Wise and Baumgartner (1999)
1999	A product service-system is a system of products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.	Goedkoop et al. (1999)
1999	A predesigned system of products, services, supporting infrastructure, and necessary networks that can fulfil consumers' needs on the market; a dematerialised solution to consumer needs and preferences; a new interpretation of the product value chain and ways of delivering utility to consumers that has a smaller environmental impact than separate products and services that fulfil the same function outside the system; and a self-learning system with the goal of continuous improvement.	Mont (1999)
2000	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.	Mont (2000)
2001	A pre-designed system of products, supporting infrastructure and necessary networks that fulfil a user's needs on the market, have a smaller environmental impact than separate product and services with the same function fulfillment and are self-learning.	Centre for Sustainable Design (2001)
2002	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.	Manzini et al. (2001)
2002	A pure product system is one in which all property rights are transferred from the product provider to the client on the point of sale [..]. A pure service system is one in which all property rights remain with the service provider, and the clients obtain no other right besides consuming the service. A product-service system is a mixture [..] of the above. It requires that property rights remain distributed between client and provider, requiring more or less interaction over the life time of the PSS.	Hockerts and Weaver (2002)
2002	Result of an innovative strategy that shifts the centre of the business design and sale of products only (physical) to systems offering products and services that are jointly capable of satisfying a given application.	UNEP (2002)
2002	PSS is a system of products, services, networks of actors and supporting infrastructure that continuously seeks to be competitive, satisfy customer needs and have a lower impact than traditional business models.	Mont (2002)
2003	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.	Manzini and Vezzoli (2003)
2003	A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally, PSS tries to reach the goals of sustainable development.	Brandstotter et al. (2003)
2004	PSS is a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models.	Mont (2004)
2004	A system consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.	Tukker (2004)
2004	PSS may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality.	Wong (2004)
2005	PSS can be defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands.	Van Halen et al. (2005)
2005	PSS is defined as 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'.	ELIMA (2005)
2006	Products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy.	Halme et al. (2006)
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.	Morelli (2006)
2006	A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker and Tischner (2006b)
2006	Product-service systems (PSS) are a specific type of value proposition that a business (network) offers to (or co-produces with) its clients. PSS 'consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs'. The PSS concept rests on two pillars: (i) Inherently taking the final functionality or satisfaction that the user wants to realise as a starting point of business development (instead of the product fulfilling this functionality). (ii) Elaborating the (business) system that provides this functionality with a 'greenfield' mindset (instead of taking existing structures, routines and the position of the own firm therein for granted).	Tukker and Tischner (2006a)
2006	An advanced industrialised solution based on collaboration between social players, which gives rise to both effective and efficient, highly contextualised services.	Krucken and Meroni (2006)
2007	PSS is an integrated offering of a product and a service that provides a value. Using a PSS offers the opportunity to decouple economic success from material consumption and thus reduce the environmental impact of economic activity.	Baines et al. (2007)
2007	An attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services.	Evans et al. (2007)
2009	[…] instead of assuming that all products are to be bought, owned, and disposed of by 'consumers', products containing valuable technical nutrients – cars, televisions, carpeting, computers, and refrigerators, for example – would be reconceived as services people want to enjoy. In this scenario, customers (a more apt term for the users of these products) would effectively purchase the service of such a product for a defined user period…, rather than the … [product] itself.	McDonough and Braungart (2009)
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.	Azarenko et al. (2009)
2009	PSS is an integrated product and service offering that delivers value in use.	Neely (2009)
2009	PSS is system of products and services (and infrastructure), to jointly cope with the needs and demands of customers in a more efficient way with better value for both businesses and customers, compared to only offering products […]. PSS can decouple the creation of value from the consumption of materials and energy and thus significantly reduce the environmental impact in the life cycle of traditional product systems.	Tischner et al. (2009)
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.	Jiang and Fu (2009)
2009	IPS2 can be described as a marketable set of products and services capable of jointly fulfilling a user's need.	Rese et al. (2009)
2010	PSS is an innovation strategy, where a greater integration of products and services has the potential to decouple business success and economic growth from mere product sales. Instead of viewing a product as an isolated entity, the PSS design activity focuses on creating the right combination of products and services, needed to aid the customer in reaching their goal.	Proteus (2010)

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Table B1 (*continued*)

Year	PSS definitions	Source
2010	An Industrial Product-Service System is characterised 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.	Meier et al. (2010)
2011	Elements of PSS are: product, service, and supporting networks and infrastructure and goals of PSS are: strives to be competitive; maximum customer value; lower environmental impact.	Wang et al. (2011)
2011	PSS is defined as a solution for optimal resource operations in product life cycle through integrating tangible products with intangible services.	Zhu et al. (2011)
2011	By supplying an integrated bundle of hardware, software, and service elements, the customer problem is solved completely. These bundles are known as product service systems (PSS) or hybrid products.	Berkovich et al. (2011)
2011	Industrial product–service system, also known as technical-PSS, is a specific case of PSS, which focuses on provision of services for a product core that has a high net value and involves transactions in a B2B context.	Erkoyuncu et al. (2011)
2011	The combination of existing physical products with value adding services to so called industrial product service systems (IPS2) is a promising approach for differentiation and, therefore, strengthening of the competitive position.	Schuh et al. (2011)
2011	IPS2 are based upon product-service systems that can be defined as customer life cycle-oriented combinations of products and services to provide a higher customer value.	Meier et al. (2011)
2012	An Integrated Product Service System (iPSS) "is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life cycle".	Zhang et al. (2012)
2012	Integrated Service Products (ISP), in the product sales stage, to meet the clients' multi-level needs, the manufacturer provides customers with "physical product plus service" service packs; whereas, physical product is the carrier of product service, and product services are function added and the value added for the physical product. However, since the ISP combines.	Li et al. (2012)
2012	Products and services are integrated and provided as whole set to fulfil customer's requirements and the product/service ratio can vary in different customer using contexts.	Geng and Chu (2012)
2013	Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value.	Boehm and Thomas (2013)
2013	PSS is an integrated offerings of tangible products, intangible services and the enabling infrastructure providing a product-unspecific functional value. While the user and the offering firm engage into an enduring contractual relationship, the ownership remains with the offering firm with the user becoming the temporary proprietor enabling a high use-flexibility.	Tietze et al. (2013)
2014	PSS is an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction') based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally beneficial new solutions.	Vezzoli et al. (2014)
2014	A product-service system (PSS) is an integrated combination of products and services for optimal consumption.	Centenera and Hasan (2014)
2014	A PSS is a system composed of a physical product and associated services that support the product through-life.	McKay and Kundu (2014)
2015	A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker (2015)
2016	A product-service system (PSS) is an industrial offer resulting from an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific and customised client demands.	Boucher et al. (2016)
2016	PSS is a business model focused towards 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.	Annarelli et al. (2016)
2020	PSS are integrated offerings of products and services which can bring innovative potential, securing competitiveness while at the same time allowing companies to address environmental concerns.	Annarelli et al. (2020)
2021	PSS solution is sustainable product-service systems (SPSS), which improve product-service value through customer empathy, innovation activities, cultural capability, partnerships, product-service assurance and corporate social responsibility	Negash et al. (2021).

Appendix C

Table C1
Evolution of main SPSS definitions.

Year	SPSS definition	Source
2001	Eco-efficient services are systems of products and services which are developed to cause a minimum environmental impact with a maximum added value.	Brezet et al. (2001)
2001	An eco-efficient service is one which reduces the environmental impact of customer activities per unit of output. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient).	James et al. (2001)
2003	Sustainable Product and Service Development is defined here as the process of making products and/or services in a more sustainable way throughout their entire lifecycle, from conception to end of life. The products and/or services are developed to be more sustainable in a Triple Bottom Line (TBL) context (balancing economic, environmental and social aspects). This is interpreted as achieving an optimum balance between environmental protection, social equity, and economic prosperity, while still meeting traditional product requirements, e.g. quality, market, technical and cost issues.	Maxwell and van der Vorst (2003)
2006	Sustainable Product and/or Service Development (SPSD) approach is a pragmatic industry support encompassing a range of strategies aimed at maximising environmental and social performance in all types of "offerings" whether they are "products", "services" or Product Service Systems (PSS).	Maxwell et al. (2006)
2014	Product-Service System Design for Sustainability is defined as: "the design of the system of products and services that are together able to fulfil a particular customer demand (deliver a 'unit of satisfaction') based on the design of innovative interactions of the stakeholders (directly and indirectly linked to that 'satisfaction' system) where the economic and competitive interest of the providers continuously seeks both environmentally and socio-ethically beneficial new solutions.	Vezzoli et al. (2014)
2015	A SPSS means that product-service solutions should generate satisfactory value for customers and fulfil the sustainability requirements at the same time.	Chou et al. (2015)
2015	SPSS is "an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions".	Vezzoli et al. (2015)
2016		Barquet et al. (2016b)

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Table C1 (*continued*)

Year	SPSS definition	Source
	A SPSS business model is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilisation and dematerialisation, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage.	
2018	"The SPSS is a concept through which businesses can improve their economic and environmental performance. Hence, this concept demands high levels of innovation in products by analyzing the demands of customers for products or services to satisfy their perceptions and gathering the results as the foundation of innovation".	Tseng et al. (2018)
2019	A sustainable PSS (SPSS) is based on economic, social and environmental provisions while satisfying customer needs. An SPSS covers the process from production to consumption and should consider the product life cycle.	Tseng et al. (2019a, 2019b)
2019	SPSS can be defined as an offer model that provides an integrated mix of products and services that are able to fulfil a particular customer demand.	de Jesus Pacheco et al. (2019)
2019	SPSS is a relatively recent business model that combines tangible products and intangible services to satisfy customer demand. It may be defined as firms integrating products with services to systematically provide functions for replacing tangible products. This type of model is based on interactions between the stakeholders of the triple bottom line, economy, society, and environment, to improve the sustainability of supply chain management.	Kuo et al. (2019)
2020	The SPSS is a concept through which businesses can improve their economic and environmental performance.	Tseng et al. (2019b)
2020	SPSS have emphasised end-of-pipe attitudes and dematerialisation strategies to fulfil the needs of customers in more sustainable and life-cycle oriented ways.	Wang et al. (2020)
2021	SPSS combine products and services to satisfy customer needs by replacing tangible values with intangible values, such as risk reduction, flexibility and sustainability. SPSS offer product-service value and sustainability value; however, firms must consider sustainability in both consumption and production operations.	Negash et al. (2021)
2021	A successful SPSS means satisfying the value expectations from different kinds of stakeholders simultaneously. […] the multiple value elements of sustainable PSS are illustrated from four dimensions: customer value perceptions, customer service demands, sustainability potentials and partnership establishment.	Liu et al. (2021)

Appendix D

Table D1
SPSS textual definitions used in NLU analysis.

SPSS definitions	Author (s)
…are systems of products and services which are developed to cause a minimum environmental impact with a maximum added value.	Brezet et al. (2001)
…is one which reduces the environmental impact of customer activities per unit of output. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient).	James et al. (2001)
…the process of making products and/or services in a more sustainable way throughout their entire lifecycle, from conception to end of life. The products and/or services are developed to be more sustainable in a Triple Bottom Line (TBL) context (balancing economic, environmental and social aspects). This is interpreted as achieving an optimum balance between environmental protection, social equity, and economic prosperity, while still meeting traditional product requirements, e.g. quality, market, technical and cost issues.	Maxwell and van der Vorst (2003)
…is a pragmatic industry support encompassing a range of strategies aimed at maximising environmental and social performance in all types of offerings whether they are products, services or Product Service Systems.	Maxwell et al. (2006)
…is the design of the system of products and services that are together able to fulfil a particular customer demand (deliver a 'unit of satisfaction') based on the design of innovative interactions of the stakeholders (directly and indirectly linked to that 'satisfaction' system) where the economic and competitive interest of the providers continuously seeks both environmentally and socio-ethically beneficial new solutions.	Vezzoli et al. (2014)
means that product-service solutions should generate satisfactory value for customers and fulfil the sustainability requirements at the same time.	Chou et al. (2015)
… is an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions.	Vezzoli et al. (2015)
… is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilisation and dematerialisation, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage.	Barquet et al. (2016b)
… is a concept through which businesses can improve their economic and environmental performance. Hence, this concept demands high levels of innovation in products by analyzing the demands of customers for products or services to satisfy their perceptions and gathering the results as the foundation of innovation.	Tseng et al. (2018)
… is based on economic, social and environmental provisions while satisfying customer needs. Sustainable product–service system covers the process from production to consumption and should consider the product life cycle.	Tseng et al. (2019a, 2019b)
… is an offer model that provides an integrated mix of products and services that are able to fulfil a particular customer demand.	de Jesus Pacheco et al. (2019)
… combines tangible products and intangible services to satisfy customer demand. It may be defined as firms integrating products with services to systematically provide functions for replacing tangible products. Sustainable product–service system is based on interactions between the stakeholders of the triple bottom line, economy, society, and environment, to improve the sustainability of supply chain management.	Kuo et al. (2019)
… is a concept through which businesses can improve their economic and environmental performance.	Tseng et al. (2019b)
… have emphasised end-of-pipe attitudes and dematerialisation strategies to fulfil the needs of customers in more sustainable and life-cycle oriented ways.	Wang et al. (2020)
… combines products and services to satisfy customer needs by replacing tangible values with intangible values, such as risk reduction, flexibility and sustainability. Sustainable product–service system offer product-service value and sustainability value, however, firms must consider sustainability in both consumption and production operations.	Negash et al. (2021)
… means satisfying the value expectations from different kinds of stakeholders simultaneously. […] the multiple value elements of sustainable product–service system are illustrated from four dimensions: customer value perceptions, customer service demands, sustainability potentials and partnership establishment.	Liu et al. (2021)

Table D2
PSS definitions used in NLU analysis.

PSS definitions	Author (s)
… is a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.	Goedkoop et al. (1999)
… is a predesigned system of products, services, supporting infrastructure, and necessary networks that can fulfil consumers' needs on the market; a dematerialised solution to consumer needs and preferences; a new interpretation of the product value chain and ways of delivering utility to consumers that has a smaller environmental impact than separate products and services that fulfil the same function outside the system; and a self-learning system with the goal of continuous improvement.	Mont (1999)
… is 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.	Mont (2000)
… is a pre-designed system of products, supporting infrastructure and necessary networks that fulfil a user's needs on the market, have a smaller environmental impact than separate product and services with the same function fulfillment and are self-learning.	Centre for Sustainable Design (2001)
… is 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.	Manzini et al. (2001)
… is a pure product system is one in which all property rights are transferred from the product provider to the client on the point of sale [..]. A pure service system is one in which all property rights remain with the service provider, and the clients obtain no other right besides consuming the service. A product-service system is a mixture [..] of the above. It requires that property rights remain distributed between client and provider, requiring more or less interaction over the life time of the PSS.	Hockerts and Weaver (2002)
… is the result of an innovative strategy that shifts the centre of the business design and sale of products only (physical) to systems offering products and services that are jointly capable of satisfying a given application.	UNEP (2002)
… is a system of products, services, networks of actors and supporting infrastructure that continuously seeks to be competitive, satisfy customer needs and have a lower impact than traditional business models.	Mont (2002)
… is 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.	Manzini and Vezzoli (2003)
… consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally, PSS tries to reach the goals of sustainable development.	Brandstotter et al. (2003)
… is a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models.	Mont (2004)
… consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.	Tukker (2004)
… is a solution offered for sale that involves both a product and a service element, to deliver the required functionality.	Wong (2004)
… is a the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands.	Van Halen et al. (2005)
… is 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'.	ELIMA (2005)
… are products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy.	Halme et al. (2006)
… is a social construction, based on attraction forces, such as goals, expected results and problem-solving criteria, which catalyse the participation of several partners. Product service-system 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.	Morelli (2006)
… consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker and Tischner (2006b)
… is a specific type of value proposition that a business (network) offers to (or co-produces with) its clients. Product service-system consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs. The Product service-system concept rests on two pillars: (i) Inherently taking the final functionality or satisfaction that the user wants to realise as a starting point of business development instead of the product fulfilling this functionality. (ii) Elaborating the business system that provides this functionality with a greenfield mindset instead of taking existing structures, routines and the position of the own firm therein for granted.	Tukker and Tischner (2006a)
… is an advanced industrialised solution based on collaboration between social players, which gives rise to both effective and efficient, highly contextualised services.	Krucken and Meroni (2006)
… is an integrated offering of a product and a service that provides a value. Using a product service-system offers the opportunity to decouple economic success from material consumption and thus reduce the environmental impact of economic activity.	Baines et al. (2007)
… is an attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services.	Evans et al. (2007)
[…] instead of assuming that all products are to be bought, owned, and disposed of by 'consumers', products containing valuable technical nutrients – cars, televisions, carpeting, computers, and refrigerators, for example – would be reconceived as services people want to enjoy. In this scenario, customers (a more apt term for the users of these products) would effectively purchase the service of such a product for a defined user period…, rather than the … [product] itself.	McDonough and Braungart (2009)
… emphasises the physical product core enhanced and customised by a mainly non-physical service shell the investment character of all product service-system components, the relatively bigger importance of the physical core of Product service-system and the relation between product service-system manufacturers and customers.	Azarenko et al. (2009)
… is an integrated product and service offering that delivers value in use.	Neely (2009)
… is a system of products and services (and infrastructure), to jointly cope with the needs and demands of customers in a more efficient way with better value for both businesses and customers, compared to only offering products […]. Product service-system can decouple the creation of value from the consumption of materials and energy and thus significantly reduce the environmental impact in the life cycle of traditional product systems.	Tischner et al. (2009)
… is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life-cycle.	Jiang and Fu (2009)
… is a marketable set of products and services capable of jointly fulfilling a user's need.	Rese et al. (2009)
… is an innovation strategy, where a greater integration of products and services has the potential to decouple business success and economic growth from mere product sales. Instead of viewing a product as an isolated entity, the product service-system design activity focuses on creating the right combination of products and services, needed to aid the customer in reaching their goal.	Proteus (2010)
… is characterised 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.	Meier et al. (2010)
… are product, service, and supporting networks and infrastructure and goals of Product service-system are strived to be competitive; maximum customer value; lower environmental impact.	Wang et al. (2011)
… is a solution for optimal resource operations in the product life cycle through integrating tangible products with intangible services.	Zhu et al. (2011) Berkovich et al. (2011)

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Table D2 (*continued*)

PSS definitions	Author (s)
By supplying an integrated bundle of hardware, software, and service elements, the customer problem is solved completely. These bundles are known as product service systems or hybrid products.	
… is a specific case of product service-system, which focuses on provision of services for a product core that has a high net value and involves transactions in a B2B context.	Erkoyuncu et al. (2011)
The combination of existing physical products with value-adding services to so-called industrial product service systems is a promising approach for differentiation and, therefore, strengthening of the competitive position.	Schuh et al. (2011)
… are based upon product-service systems that can be defined as customer life cycle-oriented combinations of products and services to provide a higher customer value.	Meier et al. (2011)
… is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life cycle.	Zhang et al. (2012)
Integrated service products in the product sales stage, to meet the clients' multi-level needs, the manufacturer provides customers with physical product plus service service packs; whereas, physical product is the carrier of product service, and product services are function added and the value added for the physical product.	Li et al. (2012)
Products and services are integrated and provided as whole set to fulfil customer's requirements and the product/service ratio can vary in different customer using contexts.	Geng and Chu (2012)
… is an integrated bundle of products and services which aims at creating customer utility and generating value.	Boehm and Thomas (2013)
… is an integrated offering of tangible products, intangible services and the enabling infrastructure providing a product-unspecific functional value. While the user and the offering firm engage in an enduring contractual relationship, the ownership remains with the offering firm with the user becoming the temporary proprietor enabling a high use-flexibility.	Tietze et al. (2013)
… is an offering model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction') based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally beneficial new solutions.	Vezzoli et al. (2014)
… is an integrated combination of products and services for optimal consumption.	Centenera and Hasan (2014)
… is a system composed of a physical product and associated services that support the product through-life.	McKay and Kundu (2014)
… consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker (2015)
… is an industrial offer resulting from an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific and customised client demands.	Boucher et al. (2016)
… is a business model focused towards 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.	Annarelli et al. (2016)
… are integrated offerings of products and services which can bring innovative potential, securing competitiveness while at the same time allowing companies to address environmental concerns.	Annarelli et al. (2020)
… methodology for customizing solutions to different patterns of use while achieving a better environmental performance than a stand-alone product.	Haber and Fargnoli (2021)
… is sustainable product-service systems, which improve product-service value through customer empathy, innovation activities, cultural capability, partnerships, product-service assurance and corporate social responsibility	Negash et al. (2021).

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