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Review

Development and Future Trends of Digital Product-Service Systems: A Bibliometric Analysis Approach

Slavko Rakic [1,*], Nenad Medic [1], Janika Leoste [2], Teodora Vuckovic [1] and Ugljesa Marjanovic [1]

[1] Faculty of Technical Science, University of Novi Sad, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia; medic.nenad@uns.ac.rs (N.M.); teodora.lolic@uns.ac.rs (T.V.); umarjano@uns.ac.rs (U.M.)
[2] School of Educational Sciences, Tallinn University, 10120 Tallinn, Estonia; leoste@tlu.ee
* Correspondence: slavkorakic@uns.ac.rs

Abstract: As a plan, Industry 4.0 encourages manufacturing companies to switch from conventional Product-Service Systems to Digital Product-Service Systems. Systems of goods, services, and digital technologies known as "Digital Product-Service Systems" are provided to improve consumer satisfaction and business success in the marketplace. Previous studies have looked into various elements of this area for industrial companies and academic institutions. Digital Product-Service Systems' overall worth and expected course of growth are still ignored. The authors use bibliometric analysis to organize the body of prior knowledge in this discipline and, more significantly, to identify areas for further study in order to cover the literature deficit. The results of the most esteemed authors, nations, and sources in the subject were given by this study. The findings also show that terms like digitization, sustainability, and business have grown in popularity over the previous year. This study also offered insight into how Industry 5.0, a new manufacturing strategy, would include Digital Product-Service Systems. Finally, the findings of this research demonstrate three new service orientations, namely resilient, sustainable, and human-centric, in manufacturing firms.

Keywords: Digital Product-Service Systems; digital servitization; Industry 4.0; Industry 5.0; bibliometric analysis

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1. Introduction

Manufacturing companies' business strategies are evolving thanks to Industry 4.0 [1]. Additionally, Industry 4.0 integrates digital technologies, like IoT [2], Big Data [3], and AI, into the process of producing goods [4]. Its objective is to create smart, networked machines that enable real-time monitoring, adaptive manufacturing, and data-driven decision-making in order to increase efficiency and production [5,6]. Industry 4.0 stimulus manufacturing firms involved in research and development activities in the field of Product-Service Systems (PSS) [7]. Furthermore, smart factories and PSS are inextricably linked, since both ideas use digital technology to change traditional manufacturing processes into more efficient, flexible, and customer-centric operations [8,9]. They exchange data, procedures, and goals in order to produce products and services in a smooth and customer-centric manner [10]. They help businesses to react to changing market needs, create tailored experiences, and constantly enhance their offers by working together [11]. Figure 1 shows the concept of the smart factory.

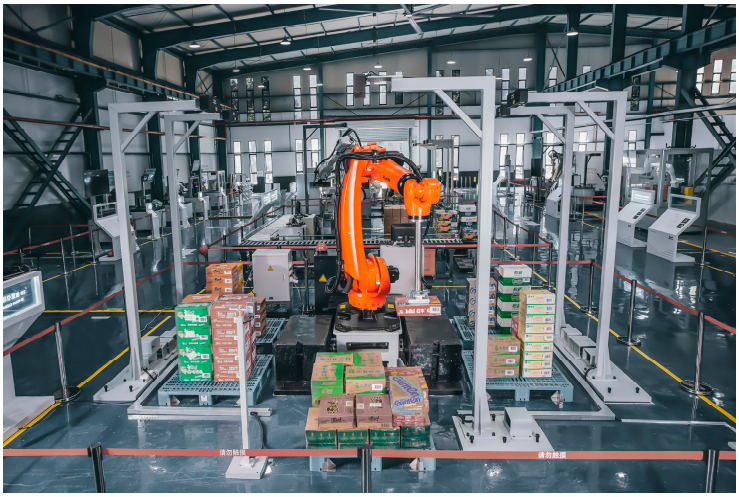

Figure 1. Smart Factory Concept [12].

This smart factory idea allows PSS to have a greater effect on the environment, allowing sustainable growth [13]. Moreover, research and development activities in fields of PSS provide insights into the new focuses of manufacturing, such as digitalization, sustainability, resilience, service orientation, and similar new contexts [14,15]. Manufacturing companies also attempt to add more digital components to the services they provide alongside their goods [16]. The transition from conventional PSS to digital PSS is, thus, supported by Industry 4.0 ideas [17,18]. Many studies began by looking into established ideas, like servitization and product-related services, but they now concentrate more on digital servitization or digital services that are provided alongside goods [19]. To ensure client happiness, digital PSS offers a combination of goods, services, and cutting-edge technologies [20]. Additionally, Digital PSS allows industrial companies to outperform their competitors in the market [21]. The previous studies attempted to examine the significant impacts of the benefits of PSS, such as client loyalty, profit, income, and market diversity, in accordance with the various benefits offered by Digital PSS [22]. Furthermore, Digital PSS are in favor of the new production approach known as Industry 5.0 [23]. The transformation in the connection between people and the automated systems that are already widespread in production contexts is the starting point for Industry 5.0 [24]. Figure 2 shows the practical applications of robots in Industry 5.0.

Figure 2. Usage of robotics in manufacturing processes [25].

Cobots, which can operate alongside human operators, are developing as critical components of Industry 5.0 [26]. These robots are intended to supplement human abilities by undertaking repetitive, risky, or physically demanding activities [11]. Cobots thrive in activities requiring frequent changeovers and flexibility, allowing quick adjustments in production to suit changing market needs [27]. Furthermore, cobots outfitted with sophisticated sensors and vision systems assure constant product quality by identifying faults and abnormalities in real time. Manufacturing companies can become more resilient, viable, and able to build relationships with their stakeholders thanks to digital PSS [28]. Different groups of stakeholders, including manufacturers, vendors, sellers, maintenance staff, and consumers, are included in digital PSS and linked to one another via various digital technologies [29,30]. Some studies, on the other hand, indicate that in some instances, the implementation of digital PSS in manufacturing companies results in poor performance [31]. One of the primary reasons is that manufacturing firms do not know what types of digital services they should include in their product offerings based on their innovative or technological level [32]. Firms are incorporating more sophisticated digital tools and services, resulting in a servitization paradox [33]. The servitization paradox occurs when a corporation invests more in service offerings in addition to products, but this results in poor performance [34]. Firms must identify their maturity level for adopting digital PSS in order to endure these challenges [35]. Firms must develop technical, organizational, and integrative approaches in order to guarantee a sufficient maturity level for the application of digital PSS ideas [36,37]. In order to generate value through smart services, smart goods and the environments in which they operate certain technological standards must adhere to the principles of [38]. The firm's maturity characteristics represent the all-encompassing, "socio-technical" perspective that designers and producers of smart services must embrace [39]. Past authors also discuss organizational issues related to digital PSS, including the corporate framework, culture, and employee readiness for new digital products and services [40]. There is still a gap in the literature that will adequately summarize the study of digital PSS [41]. Additionally, Industry 5.0 will raise a fresh query regarding the advancement of Digital PSS and its future [42,43]. Furthermore, recent research in the realm of digital PSS highlights various types of PSS transformations [44,45]. These studies also underscore the customer-centric, iterative, and agile nature of revenue model development for digital services, emphasizing the importance of close collaboration with key customers during the initial phases [46,47]. Within this context of the new digital PSS business model, past authors illustrate strategies for firms to enhance their revenue streams through service offerings [48]. Moreover, in today's digital era, the collection and utilization of data from interconnected sources offer substantial potential for value creation in service provisioning [49,50]. Lastly, it is worth noting that the primary thrust for the implementation of digital PSS is transitioning from larger enterprises to smaller and medium-sized firms, with a particular emphasis on fostering sustainable business models [51]. However, the prior bibliometric studies only focused on traditional PSS and servitization [52,53]. The bibliometric study of the Digital PSS are still forgotten [53]. The aim of this study is to bridge the existing gap in the literature by conducting a comprehensive investigation into the implementation and implications of digital PSS in the context of manufacturing firms. To fill the gap in the literature, this study will conduct a bibliometric analysis specifically focused on digital PSS. The bibliometric analysis approach objectively analyses academic literature [34]. A bibliometric analysis uses quantitative methods to examine publication characteristics and trends within a specific research domain, whereas a scientific literature review uses qualitative analysis to synthesize and critically assess existing research on a specific topic, providing a comprehensive overview of the field [47,54]. The bibliometric study aims to demonstrate the state of the research area, among other things. Using this strategy, the researcher can gather enough data for an impartial analysis using a systematic, repeatable review process, increasing the review's dependability and quality. Moreover, using this method allows authors to discover all pertinent data regarding the articles, including the most influential authors, organizations, nations, most

frequently used terms, most pertinent sources, and similar issues [34]. This technique gives researchers access to a central information source about their study area. This approach also makes it possible for researchers to visualize the data related to the papers. Consequently, text- and data-based analytic methods could be used by researchers. Zhou and Song have conducted bibliometric research in the area of servitization to demonstrate the evolution of servitization over the previous 20 years [33]. Khanra et al. also used the bibliometric analysis method to examine the potential tendency toward servitization [29]. Additionally, a study by Bartolacci, Caputo, and Soverchia used a bibliometric analysis method to only analyze the papers from the literature reviews in the manufacturing transformation [35]. Although previous studies have used bibliometric analysis to explore the evolution of servitization and examine the potential tendencies in this area, there is a significant gap in the literature regarding the application of bibliometric methods to understand the domain of digital servitization or digital PSS. The primary objective of the research is to bridge this gap by conducting a comprehensive bibliometric analysis in the field of digital PSS. By utilizing text- and data-based analytic methods, this study aims to visualize and analyze the data related to the papers in this domain. This approach will enable researchers to gain valuable insights into the evolution, trends, and potential tendencies of digital servitization over a specific period. To accomplish this objective, this study will draw upon the bibliometric analysis method used in prior research on manufacturing transformation literature reviews. By analyzing the existing body of literature, this research aims to summarize the current state of knowledge, identify key research gaps, and contribute to the overall understanding of digital PSS within the context of manufacturing firms. Furthermore, this study seeks to advance the understanding of digital PSS in the manufacturing sector, considering the implications of Industry 4.0 and Industry 5.0. By addressing the research objectives outlined above, this study aims to provide valuable insights for manufacturing firms, researchers, and practitioners interested in effectively implementing and leveraging digital PSS to drive innovation, competitiveness, and stakeholder relationships. In light of this point, the authors suggested the following research questions:

- RQ1: *Which prestigious authors, countries, and sources have made the biggest contributions to the digital PSS literature?*
- RQ2: *Which significant subject areas come to light in the digital PSS literature?*
- RQ3: *What are the future research trends of digital PSS?*

To address the presented research questions, the authors organize the manuscript as follows: Section 2 explains the bibliometric analysis procedure, and Section 3 provides the content analysis of the papers that have had the most impact on the development of digital PSS. This study's contributions are presented in Section 4, along with its major theoretical implications. The major conclusions are summarized in Section 5, which also provides future study implications.

2. Methodology

Data Collection and Analysis

One of the most popular databases for bibliometrics research, Scopus, was used by the authors to gather their data. The authors made the decision to gather information from all pertinent journals and conference papers that were listed in the Scopus database. Scopus is a large and well-known bibliographic database that includes a wide range of fields. Our decision to use Scopus was based on the greater range of articles published in the appropriate journal and conference proceedings in the field of digital PSS. The following collection of terms was used in this study: (TITLE-ABS-KEY ("digital product-service system*") OR TITLE-ABS-KEY, ("digital servitization") OR TITLE-ABS-KEY, ("servitization 4.0") OR TITLE-ABS-KEY, ("digital service business model*" AND "manufacturing") OR TITLE-ABS-KEY, ("digital product-related service*") OR TITLE-ABS-KEY, ("smart product-service systems*") OR TITLE-ABS-KEY, ("digital services in manufacturing")). Only papers submitted in English were subject to evaluation from 2014 to 2022 during the examination period for published papers. The authors picked a timeline beginning in January 2014,

since that is when the first publication in the field of digital PSS was issued. Prior to this time, servitization research was mostly focused on classical PSS. December 2022 was utilized as a crucial date to finish a 9-year time span, which is the focus of our proposed research. The authors created a thorough search strategy that made use of a variety of relevant keywords, topic areas, and publishing kinds. This method sought to cast a wide net and collect a varied range of publications, lowering the danger of overlooking relevant studies. Within the confines of our study topic (i.e., digital PSS), the authors' inclusion criteria were intended to be as inclusive as possible. By collecting a wide range of papers, the authors wanted to reduce the unintended omission of research that might provide significant insights. According to this strategy, the authors conducted a sensitivity analysis and validation of key results to ensure that all papers are in the field of digital PSS according to the mentioned string. Through this analysis, the authors detected 20 papers that are not in the field of digital PSS, and according to this finding, they reduced the database from 280 to 260 papers. The graphical analysis of the bibliographic data was performed using VOSviewer software 1.6.19. Figure 3 depicts the data collection and analysis procedure.

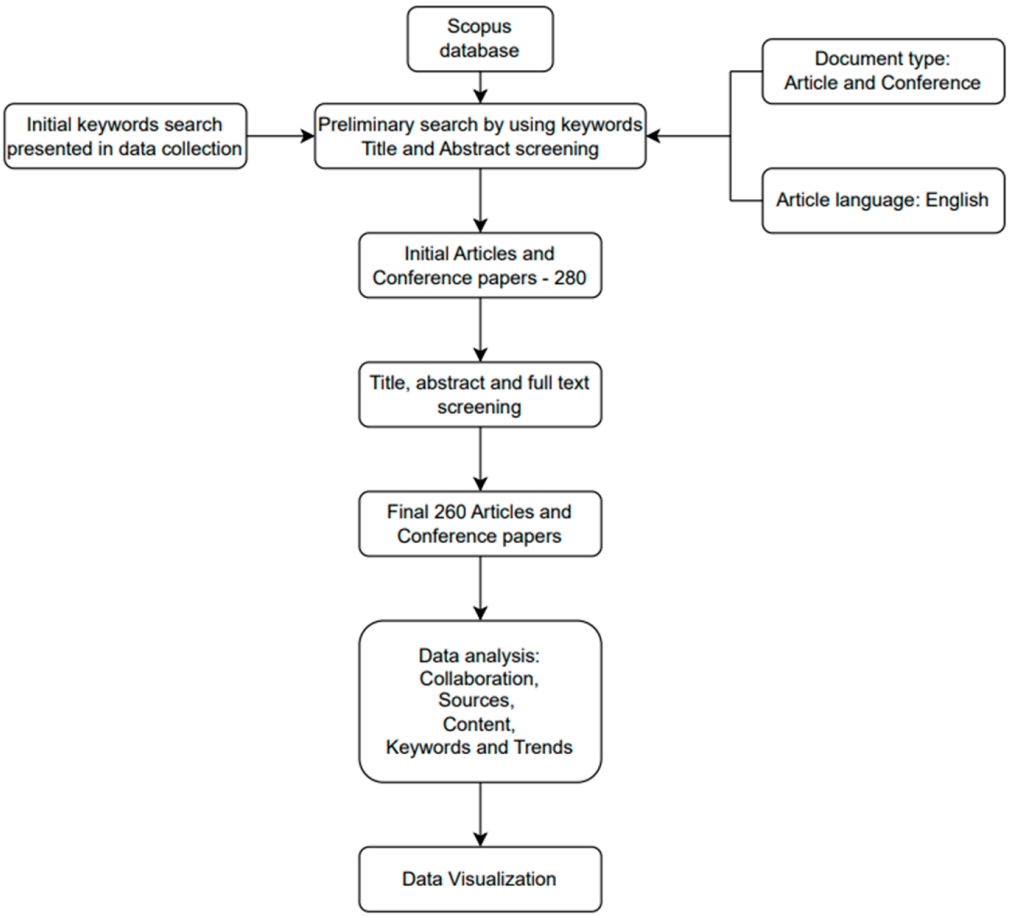

Figure 3. Data collection and analysis procedure.

The authors began the data analysis process after the data collection process, in accordance with the suggested study structure. Understanding the author, company, and country cooperation, as well as information dissemination, benefits from collaboration analysis. A network of authors who reference one another was presented via co-citation analysis, along with information on the influence of the authors and articles in the area. The most pertinent journals and conferences that released articles in the area were revealed by a study of related sources. Researching the co-occurrence of keywords is an effective way to look into scholarly areas, as well as potential future effects and directions of study. The 260 research papers used in this study are linked to the top five topic areas listed as follows:

engineering (53%); business, management, and accounting (50%); computer science (47%); decision sciences (21%); and environmental science (11%). Furthermore, this database includes 95 pertinent sources, 162 journal articles, and 98 conference papers. The average number of citations per article is 19.93, and the overall number of references is 12710. The overall number of authors is 587, with foreign co-authorship accounting for 42.53% of the total. Finally, the yearly growth rate for articles in this area was 62.24%.

3. Research Outputs

According to the research question, "*Which prestigious authors, countries and sources have made the biggest contributions to the digital PSS literature?*", the authors present the results of collaboration and source analysis. Moreover, to provide answers to the research questions "Which significant subject areas come to light in the digital PSS literature?" and "What are the future research trends of digital PSS?", the authors present the results of content, keyword, and trend analysis.

3.1. Collaboration Analysis

3.1.1. Author Collaboration Network

The author collaboration network highlights the most successful authors working in the area of digital PSS, as well as their own network of collaboration. The most productive authors in this field are shown in Table 1.

Table 1. The most relevant authors based on the number of papers.

Rank	Author	Country	h-Index	No. Citations	No. Articles
1	Pai Zheng	Hong Kong	30	3083	30
2	Chen Chun-Hsien	Singapore	38	4649	23
3	Vinit Parida	Sweden	45	7308	20
4	Zuoxu Wang	China	11	624	19
5	Xinguo Ming	China	34	3310	18
6	Marko Kohtamäki	Finland	33	3761	14
7	Xinyu Li	China	14	770	13
8	David Sjödin	Norway	26	2580	13
9	Zhihua Chen	China	9	457	11
10	Federico Adrodegari	Italy	14	1051	10
11	Ugljesa Marjanovic	Serbia	12	531	8
12	Slavko Rakic	Serbia	9	176	8
13	Mario Rapaccini	Italy	15	1273	8
14	Wenyan Song	China	29	2591	8
15	Xianyu Zhang	China	13	681	8
16	Giuditta Pezzotta	Italy	21	1544	7
17	Nicola Saccani	Italy	27	3201	7
18	Tongtong Zhou	China	5	228	7
19	Heiko Gebauer	Germany	41	6378	6
20	Tuomas Huikkola	Finland	7	295	6

Based on the author's collaboration analysis, our results show that 7 of the top 20 productive authors come from China. They are followed by four authors from Italy and two each from Finland and Serbia. The average number of citations per 20 authors is 2212, and the average number of papers in the field is 12. Figure 4 shows the collaboration analysis of the most productive authors.

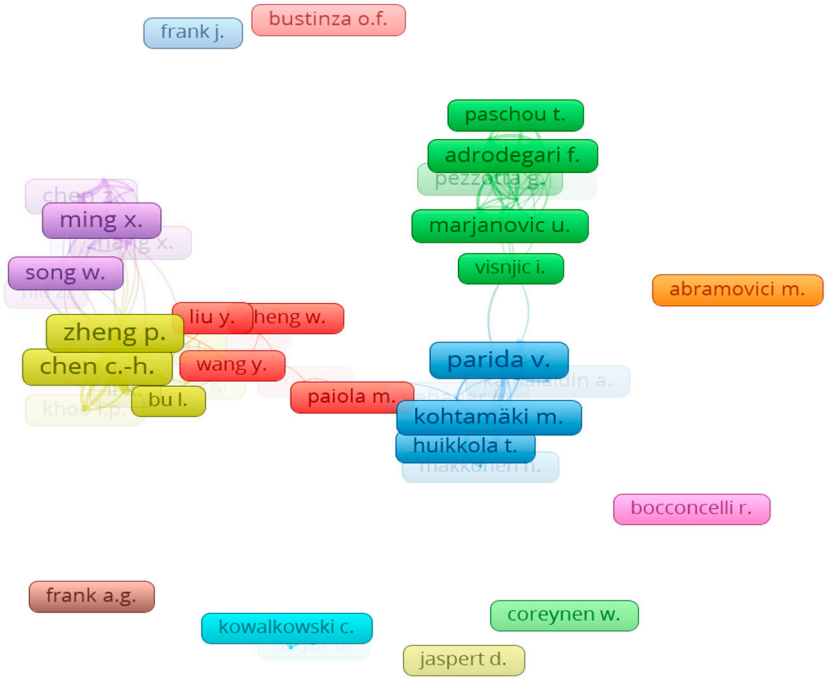

Figure 4. The network analysis of authors' collaboration.

Figure 2 shows the top ten clusters of authors in the field of digital PSS. According to the findings of this cluster analysis, the Asians scholars' cluster, which is headed by Pai Zheng, Chen Chun-Hsien, and Zuoxu Wang, produces the majority of the network's most significant authors. The grouping led by the Scandinavians authors Vinit Parida and Marko Kohtamäki comes after them. Finally, yet importantly, the Italian and Serbian authors, who have strong ties to the IFIP Advances in Information and Communication Technology group, lead the third most important cluster in the area of digital PSS.

3.1.2. Country Collaboration Network

The most frequently cited nations globally in the area of digital PSS are shown in Table 2.

Table 2. The average number of citations per paper by country.

Rank	Country	Total Citation	Average Citations Per Article
1	United Kingdom	410	68
2	Sweden	806	47
3	Finland	601	46
4	Spain	148	37
5	Singapore	592	35
6	Italy	433	24
7	France	112	22
8	China	1032	18
9	Hong Kong	126	18
10	Germany	195	9

The UK has the most citations per document (68), according to a study of the average number of citations per paper by nation. Sweden, Finland, Spain, and Singapore, along with the UK, round out the top five countries by the average amount of citations. China has 1032 citations overall, making them the nation with the most citations overall, but they average 18 citations per article. Figure 5 depicts the international cooperation network for digital PSS.

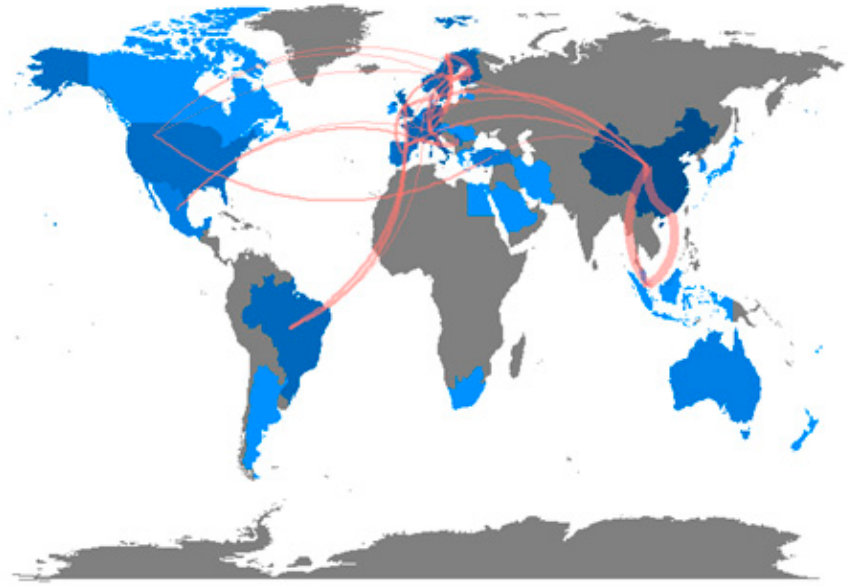

Figure 5. The network analysis of country collaboration.

The outcomes of the national network partnerships demonstrate the state of digital PSS research globally. With 16 papers, China, Hong Kong, and Singapore have the greatest ties between authors from various nations. Then, 8–10 papers follow them on Scandinavian cooperation between Sweden, Finland, and Norway. With six jointly written papers, Italian cooperation with France and Serbia ranks in the top ten of the nation collaboration rankings. Finally, Switzerland and Sweden worked together on five articles in cooperation with the UK and Spain.

3.2. Sources Analysis

The sources analysis shows the most relevant international journals and conferences that are related to the field of digital PSS. Figure 6 shows the annual scientific production in the field of digital PSS.

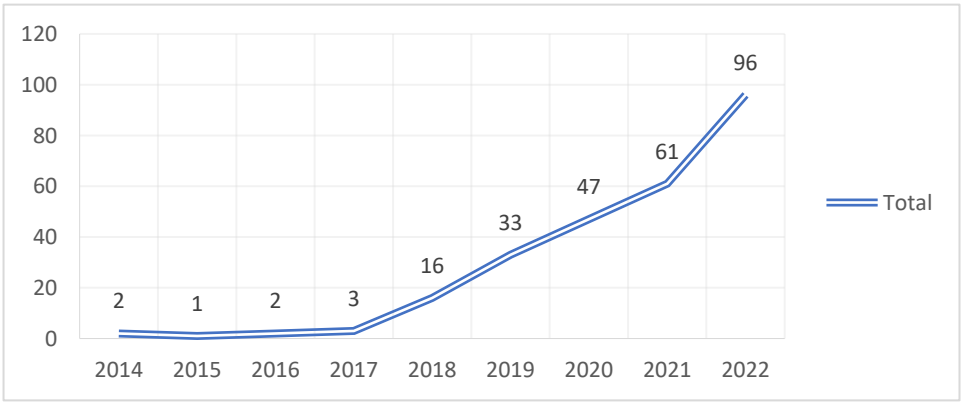

Figure 6. The annual scientific production.

The findings from the annual scientific output in the area of digital PSS demonstrate patterns that are on the rise. In particular, the significant development rate has been on the rise over the past five years. Table 3 shows the most relevant sources by the number of articles.

Table 3. The most relevant sources by the number of articles.

Rank	Source Name	Publisher	Articles
1	Advanced Engineering Informatics	Elsevier	24
2	Advances in Production Management Systems	Springer	21
3	Procedia CIRP	Elsevier	21
4	Industrial Marketing Management	Elsevier	17
5	Journal of Cleaner Production	Elsevier	15
6	Journal of Business Research	Elsevier	9
7	Technological Forecasting and Social Change	Elsevier	8
8	Computers and Industrial Engineering	Elsevier	6
9	Computers in Industry	Elsevier	6
10	Sustainability	MDPI	5

According to the findings of the most pertinent sources, nine of the ten sources are international journals, and one source is an international conference on Advances in Production Management Systems. Results also indicate that Elsevier release eight of the ten sources, along with one from Springer and one from MDPI. The average number of published articles by the top ten sources is 13.

3.3. Keywords and Content Analysis

3.3.1. Keywords and Trends Analysis

Table 4 shows the most commonly used keywords and trends in the area of digital PSS derived from the keywords and trend analysis.

Table 4. Keywords and trends analysis.

Keywords—Occurrences		Trends—Occurrences	
Smart products	84	Smart products	84
Product-Service Systems	68	Product-Service Systems	68
Product design	63	Product design	63
Servitization	47	Servitization	47
Manufacture	34	Digital servitization	25
Life cycle	30	Smart Product-Service System	23
Digital servitization	25	Service industry	17
Smart Product-Service System	23	Internet of Things	16
Industrial research	22	Value co-creations	15
Decision making	21	Embedded systems	9

The keywords and trends analysis find the same or similar words as triggers for the digital PSS. The main focus of research is on smart products, Product-Service Systems, product design, and servitization. An emerging trend in the last three years in this field is digital servitization and Smart Product-Service Systems. For the in-depth analysis, the authors performed co-occurrence keyword analysis for the period of the last three years (2020–2022) via the color scale. Figure 7 shows the co-occurrence keyword analysis.

The graph depicts a co-occurrence keyword analysis from 2020 to 2022. The purple keywords reflect terms from 2020 that are directed to traditional PSS, followed by the blue keywords from 2020 to 2021, which suggest that smart or digital PSS are more commonly used in these years. The use of green and yellow keywords indicates an emphasis on business models, Industry 4.0, sustainability, and other relevant themes from 2021 to 2022.

3.3.2. Content Analysis

Table 5 shows the brief content analysis of the most cited papers in the field of digital PSS.

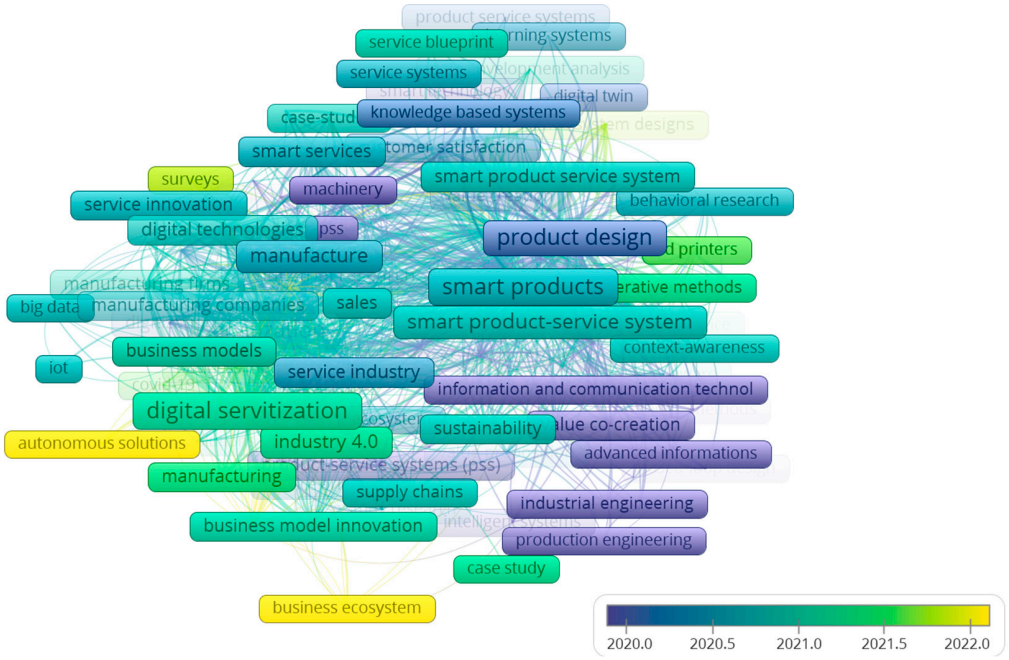

Figure 7. Co-occurrence keyword analysis.

Table 5. List of most cited papers in the field of digital PSS.

Rank	Authors	Title	No. Citations	Year of Publication
1	Vendrell-Herrero et al. [40]	Servitization, digitization, and supply chain interdependency	335	2017
2	Kohtamäki et al. [29]	Digital servitization business models in ecosystems: a theory of the firm	262	2019
3	Zheng et al. [55]	A Systematic design approach for service innovation of Smart Product-Service Systems	238	2018
4	Sklyar et al. [39]	Organizing for digital servitization: a service ecosystem perspective	203	2019
5	Kohtamäki et al. [33]	The relationship between digitalization and servitization: the role of servitization in capturing the financial potential of digitalization	154	2020
6	Paiola et al. [32]	Internet of Things technologies, digital servitization, and business model innovation in BtoB manufacturing firms	144	2020
7	Sjödin et al. [56]	An agile co-creation process for digital servitization: A micro-service innovation approach	140	2020
8	Valencia et al. [21]	The design of Smart Product-Service Systems (PSS): an exploration of design characteristics	137	2015
9	Paschou et al. [35]	Digital servitization in manufacturing: a systematic literature review and research agenda	132	2020
10	Tronvoll et al. [57]	Transformational shifts through digital servitization	130	2020

The authors explain the primary addition of the top ten cited articles in the area of digital PSS in accordance with the data presented in Table 5. In the area of digital PSS, papers released between 2017 and 2020 receive the most citations. The Vendrell-Herrero et al. article, which

has received the most citations, illustrates the connection between supply chain values and digital services when a company makes strategy decisions [40]. Two articles by Kohtamäki are among the ten most frequently referenced; one explains the business model for digital servitization and their ecosystem, and the other illustrates the connection between servitization and digitalization and how it affects financial performance [29,33]. The third most cited article by Zheng et al. shows how creative work was carried out to create Smart PSS, and it also illustrates how important PSS is to manufacturing companies' inventive efforts [55]. According to Skylar et al., organizational change occurs throughout the environment, and they recommend to-firm consolidation [39]. In order to achieve digital PSS, Paiola et al. demonstrate how digital technologies can assist industrial companies in transforming their businesses [32]. Sjödin also demonstrates how an agile micro-service innovation strategy is the most effective way to handle value co-creation in digital servitization [56]. In their study, Valenica et al. show the Smart PSS concept [21]. This research highlights the potential benefits for both customers and businesses related to the development of Smart PSS. The systematic literature analysis in the area of digital servitization is described by Paschou et al [35]. Finally, Tronvoll et al.'s paper constructed the top ten cited papers with the knowledge of the transformation through three steps—planning to finding, shortage to abundance, and dominance to partnership—to achieve digital PSS [57]. Furthermore, Figure 8 shows the thematic map for the 44 articles published in the field of digital PSS in 2023.

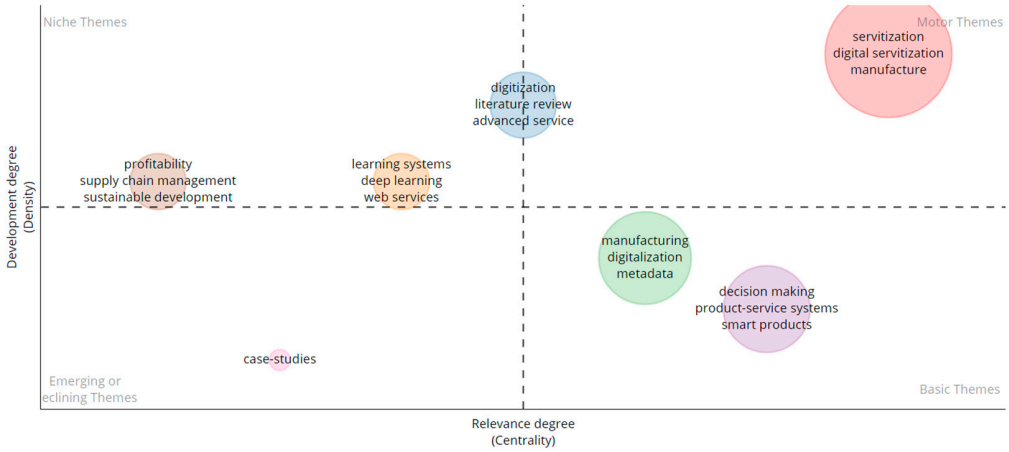

Figure 8. Digital PSS thematic map.

The thematic map depicted in Figure 6 illustrates the primary focal points within the realm of digital PSS in 2023. Within these maps, themes such as profitability and supply chain constitute niche areas, alongside deep learning and web services. Conversely, the opposing side of the map reveals fundamental themes, exemplified by Product-Service Systems and smart products. Ultimately, digital servitization and servitization emerge as pivotal themes within this context.

4. Discussion

In order to arrange the dispersed literature on digital PSS and offer a framework for future research in a field that lacks defined boundaries, this study employs bibliometric analysis. In response to RQ1, this study names the significant authors, nations, and sources influencing digital PSS research. According to this research, authors from South and East Asia (specifically China, Hong Kong, and Singapore) are the most prolific in the area, followed by those from Scandinavia. (i.e., Sweden, Finland, and Norway). Finally, the remaining top 20 most productive writers in the area of digital PSS are authors from Italy and Serbia. The construct of the 20 most prolific authors is altered when compared to earlier studies of traditional PSS. Scandinavian and British writers are the most prolific in traditional PSS. In both research groups (i.e., traditional and digital PSS), only two authors,

Vinit Parida and Marko Kohtamäki, are the most productive [33]. It seems that there are also ten clusters of authors who have close ties to one another. The strongest three clusters are from the authors mentioned above. The most frequently cited articles, on average, come from UK authors rather than those from the most productive nations. The network study of cross-national cooperation is similar to the author's origin. With 8 of the top 10 most prolific sources, Elsevier is the most successful publisher in this field. One source from Springer and one source from MDPI Publisher are then presented. This research provides a brief content analysis in reaction to RQ2 and lists the keywords that appear the most frequently. The keyword analysis shows that smart products, Product-Service Systems, product design, and servitization are the most frequently occurring keywords in the existing literature in this field. However, the future trends show that digital servitization as a keyword will construct the top five keywords in the digital PSS field. The content analysis based on keyword co-occurrence demonstrates the paper development process from traditional PSS and their transfer to digital PSS through the influence of digitalization on PSS performance and the presence and structure of PSS ecosystems. Furthermore, some novel subjects derived from keyword co-occurrence analysis indicate that blueprint and design thinking as a creative technique might be used to conduct a thorough examination of the creation of digital services in the PSS industry. Furthermore, these two methodologies (blueprinting and design thinking) are becoming more popular in service engineering, and it will be interesting to see how manufacturing organizations will use them in the future. Additionally, the brief content analysis shows that topics such as digital servitization, service business models, digital technologies and innovations, design of smart PSS, and manufacturing transformation processes are the most frequently researched areas in the most cited papers in the field of digital PSS. Furthermore, data reveal that the 10 most referenced publications span the years 2017 to 2020. Finally, the top five subject fields identified through the analysis of the research articles used in this study are engineering (53%); business, management, and accounting (50%); computer science (47%); decision sciences (21%); and environmental science (11%). This research involves a detailed analysis of the content that is provided in the area of digital PSS in answer to RQ3. The Tukker model, Frank model, and Lerch model are commonly used for PSS transformation. The Tukkers model defined the first phase of the transformation of manufacturing firms as the shift from a product- to a services-oriented business [58]. The new transformation brought about via the adoption of digital technologies was from traditional to digital PSS, as defined by the Lerchs model [59]. Additionally, the Franks model illustrates how Industry 4.0 as a whole alters the business model in industrial companies with customer-focused digital PSS [17]. Accordingly, the authors summarize the content analysis and provide an overview of key findings and insights from the ten most cited papers related to digital servitization.

- *Digital Disruption and Value Capture*: The examination begins by outlining how digital disruption impacts firms' supply chain positions. Physical product dematerialization, driven by lower manufacturing and transportation costs, has changed the way that firms interact with their customers [60]. This shift allows downstream firms to empower themselves while allowing upstream firms to capture more value through difficult-to-imitate digital services [61].
- *The Analysis of Ecosystems in Digital Servitization*: The analysis then investigates the function of ecosystems in digital servitization business models [62]. To explain how digitalization effects business models across organizational borders inside of ecosystems, four firm theories are used: Industrial Organization, Resource-Based View, Organizational Identity, and Transaction Cost Approach [63]. The alignment and appropriateness of diverse enterprises' business models inside of ecosystems is critical for effective digital servitization [64].
- *Smart PSS and Service Innovation*: The notion of Smart Product-Service Systems (Smart PSSs) and their potential for service innovation is explored in the content analysis [65]. Smart PSSs combine smart goods and e-services to provide customized services, community participation, and continual growth [9]. The analysis stresses the need for

good design frameworks and gives a case study of personalized smart wearables to demonstrate Smart PSSs' value generation potential [66].

- *Organizational Change and Digital Servitization*: The focus of the investigation moves on to organizational change processes in digital servitization [67]. These studies, which are based on in-depth interviews with management, find disparities in digital service-led development and ecosystem-related activities among firms [68]. The findings highlight the significance of within-firm centralization and integration in enabling successful digital servitization [69]. Service-centricity and cultivating an agile mentality are essential for reaping the full benefits of digitalization.
- *Financial Performance and the Interplay of Digitalization and Servitization*: These studies looks into the links between digitalization, servitization, and financial performance [70]. The interaction between low-to-moderate levels of digitalization and significant servitization has a detrimental influence on financial performance [71]. However, when digitalization increases from moderate to high levels, the interaction improves the financial performance. These findings emphasize the importance of servitization in boosting financial success as a result of digitalization.
- *The Internet of Things' Impact on Service-Oriented Business Models*: This study focuses on how the Internet of Things (IoT) affects service-oriented business models in B2B manufacturing firms [72]. It stresses the benefits and problems provided by IoT technology, as well as the significance of sales models in influencing organizations' digital servitization strategies. This research contributes by distinguishing incremental levels of complexity based on the usage of IoT technology and offering a map of digital servitization.

This analysis adds to the existing literature by synthesizing and summarizing the present state of knowledge on the topic of digital servitization. Based on the existing knowledge and the findings from this research, the authors propose the future development of digital PSS using the new manufacturing strategy Industry 5.0. Human-centric, sustainable, and resilient are the three orientations of Industry 5.0. From the standpoint of digital PSS, the first human-centric orientation encloses customer inclusion in digital service development, which is in accordance with the keywords analysis (e.g., blueprint and design thinking), as well as the content analysis design of the digital PSS and co-creation process. From the perspective of digital PSS, the second sustainable orientation, keyword analysis reveals that one of the important keywords in the papers produced between 2021 and 2022 is sustainability. Furthermore, content analysis reveals the papers' focus on organizational procedures for digital PSS that include principles of sustainable development. Finally, the third Industry 5.0 orientation resilience resulted in digital PSS keywords and content analysis on the theme of digital technologies, which assisted manufacturing enterprises in passing through various crisis moments, such as COVID-19. Figure 9 depicts the prediction of the future development of Digital PSS.

Human-centric, sustainable, and resilient services are the three distinct types of services that the future growth of digital PSS will focus on [42]. Human-centric services are those that use digital components [73] to achieve client satisfaction and make it simple for customers to conduct business. (i.e., digital trainings, chatbots, etc.) [19]. Services with digital components and a focus on achieving the sustainable business objectives of industrial companies are referred to as sustainable services. (i.e., digital take-back services, predictive maintenance, etc.) [36,37]. Last but not least, resilience services represent services that have digital components designed to withstand environmental effect (e.g., COVID-19. The resilience services may be built on artificial intelligence (AI) technology, big data, or augmented or virtual reality [4]. These three types of services could create new digital solutions that could be offered to customers, such a combination of product and services integrated as one solution. Future developments in digital PSS may also look into networks, designs, business models, and change processes in light of Industry 5.0. Manufacturing companies will be able to run more sustainably by combining people, the environment, and new business strategies thanks to the development of digital PSS in the age of Industry 5.0.

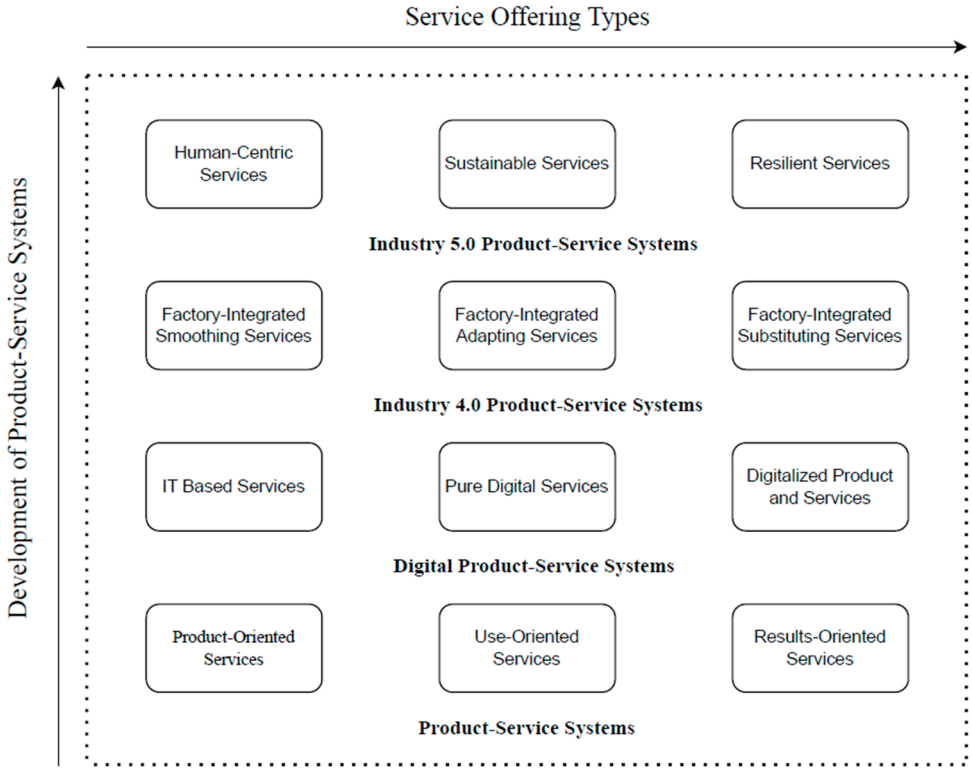

Figure 9. A conceptual framework for digital PSS and Industry 5.0 convergence.

5. Conclusions

In this study, we performed a bibliometric analysis of the digital PSS field using cooperation, content, sources, keywords, and trend analysis. By providing a thorough overview of the existing literature and tackling three research gaps related to the key authors, significant subject areas, and future research objectives in the field, this study seeks to address the dearth of digital PSS research. The findings from the research question "*Which prestigious authors, countries and sources have made the biggest contributions to the digital PSS literature?*" compile the most important bibliometric information from the Scopus database in the field of digital PSS. As a result, the answer to the research question "*Which significant subject areas come to light in the digital PSS literature?*" offers a short content analysis and key terms that highlight the main topics in the field of digital PSS. The most important topics in the field, according to the content analysis of the most cited papers, are Digital Disruption and Value Capture, the Analysis of Ecosystems in Digital Servitization, Smart PSS and Service Innovation, Organizational Change and Digital Servitization, Financial Performance and the Interplay between Digitalization and Servitization, and the Internet of Things' Impact on Service-Oriented Business Models. Finally, the response to the research question "*What are the future research trends of digital PSS?*" reveals a more in-depth conceptual paradigm for the convergence of digital PSS and Industry 5.0. These findings are confirmed by the paper's major contribution, which is a content and keyword co-occurrence analysis that reveals expanding trends in the field of digital PSS. As a result, this study is a significant addition to the body of literature because it combined earlier studies and offered a cutting-edge conceptual framework for furthering research into digital PSS. This study offers helpful information about the major contributors and major publishers of research in the field of digital PSS based on the theoretical consequences. In addition, this study theoretically demonstrates the key topics in the field of digital PSS, including digital servitization, service business models, digital technologies and advances, the design of smart PSS, and industrial transformation processes. Additionally, this research provides a forecast of the growth of digital PSS in Industry 5.0. A conceptual framework that depicts future service development based on human-centric, sustainability,

and resilience factors is provided by the main theoretical contribution. Based on these practical implications, this study demonstrates the digital PSS change processes and the dominant issue in this area. Additionally, this study reveals the most widely referenced papers that highlight the significance of ecosystems, technology, and organization in the evolution of digital PSS. The results of this research also demonstrate how Industry 5.0's new manufacturing approach could incorporate digital PSS. This study's primary practical consequence is that understanding how important services are to manufacturing firms is what drives them to utilize the right digital PSS in order to perform better and resolve the "servitization paradox" issue. However, it is important to keep in mind that there are still some limitations to this research. Refreshing the data provided by bibliometric research over time is necessary. Additionally, only the Scopus database was used to obtain the data for this study. This study's findings could only provide a summary of the relevant areas and some recommendations for the future. According to this study's limitations, the authors recommend that future research incorporates information from additional pertinent databases, such as Web of Science. Future studies are also needed to demonstrate the connection between Industry 5.0 ideas and digital PSS in manufacturing firms in order to explore the conceptual model that has been suggested in this study. Also, the results derived from the thematic maps reveal that certain AI topics, notably deep learning, may be poised to emerge as novel trends in the field of digital PSS. Future research should aim to more comprehensively investigate how AI tools can facilitate the advancement of digital service creation and offerings.

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