Product Service System in Circular Economy: A Bibliometric Analysis

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ABSTRACT

As global attention to sustainable development increases, more and more works of literature emphasise the application of a circular economy-oriented product service system (PSS).The Circular economy aims to achieve economic and environmental sustainability through efficiency of resources and minimisation of waste. Meanwhile, product service systems are an emerging business model with the potential to facilitate product life extension and recycling. However,despite the growth of this field of study, there are relatively few bibliometric analyses of its application in the circular economy. Therefore, this study aims to use the method of bibliometrics,and with the help of VOS viewer visualisation software, to analyse the relevant literature the application of product-service systems under the guidance of circular economy in Scopus database from 2014 to 2023, and to discuss the publication types and trends, source distribution of publications, the most highly cited articles, and research hotspot keywords analysis. Thisstudyfound that keyword analysis identified four main topic clusters, in which significant hotspots focused on the Internet of Things, Industry 4.0, consumer behaviour, and reverse logistics.Therefore, this study may benefit researchers who wish to understand relevant academic results circular economy-oriented PSS applications.

Keywords: *Circular economy, Bibliometric analysis, Product service system, Sustainable development.*

INTRODUCTION

In today's context of global sustainable development, the circular economy (CE) has received extensive attention (Merli et al., 2018). According to data from the United Nations Environment Program (UNEP) (2022), global municipal solid waste generation is expected to increase from approximately 2.24 billion tons in 2020 to 3.88 billion tons in 2050, which means that the amount of waste is showing a continuous growth trend. The United Nations (2023) first held International Zero Waste Day on March 30, 2023, in response to this challenge. The goal is to promote a"green"shift to sustainable production and consumption patterns, support the social transition to a circular economy, and increase awareness and participation in zero-waste initiatives. Because the traditional linear economic model has been unable to meet the sustainable development needs of society, therefore, there is a need to transform the economic model, and circular economy,as a viable solution, aims to address the interlinkages between the environment and economic activities (Andersen, 2007; Merli et al., 2018), by establishing a closed-loop circulation system Instead of the traditional open-loop setup, change the linear production and consumption pattern. Inclosed loop systems, the value of products, materials and services is kept in active use for salonga possible through the principles of recovery, reduction, and reuse (Merli et al., 2018). In short, the core concept of the circular economy is to combine economic development with resource utilisation and environmental protection and to maximise the value of products and services while reducing resource consumption and waste generation by establishing a closed-loop system.

Over time, it has become increasingly popular in various disciplines, such as environmental studies (Joensuu et al., 2020; Schwarz et al., 2021; Munaro et al., 2020), energy (Sharma et al., 2020), production and manufacturing (Bjørnbet et al., 2021; Ciliberto et al., 2021), education (Kirchherr & Piscicelli, 2019), healthcare (Boerdonk et al., 2021), etc., are widely disseminated. Supported by research and scientific reports, the CE is flourishing (Pamucar et al., 2023), stimulating people's attention and action on sustainable development. This trend helps to use resources more efficiently,reduce environmental pollution, promote economic prosperity and social progress, andlaya solid foundation for future sustainable development.

In the circular economy concept, authors such as Stahel (1982) and Schmidt-Bleek (2013)found these benefits of the product service system (PSS) concept. In addition, combined with the current renewed interest in sustainability and resource efficiency has driven the focus on PSS (Tukker, 2015). PSS is recognised as one of the powerful tools to promote a resource-efficient circular economy and achieve a much-needed "resource revolution" (Tukker, 2015), it can enable economic growth while reducing resource consumption and environmental impact (Huetal, 2012), significantly transforming products into services, changed the traditional "ownership" model, Mont (2002) put forward related solutions, such as providing product use rights, leasing products,repairing and other services, allowing users to pay more attention to the use value of products rather than ownership, minimising the impact on the environment (Coelhoet al., 2020; Matschewsky, 2019). Therefore, from product design and production to consumption and waste management, through applying PSS under the guidance of circular economy, the effective use of resources and the minimisation of waste can be realised to the greatest extent.

Although PSS has been extensively explored in theory and practice, there has been relatively little bibliometric analysis of its application in the circular economy. Currently, most studies focus on the concept, design principles and implementation methods of PSS, and there is a lack of comprehensive research and evaluation on the application of PSS in the actual circular economy.

Therefore, it is necessary to conduct a bibliometric analysis to systematically review and analyse the research on applying PSS under the guidance of the CE. We will reveal the research hotspots and

central themes of PSS application, which will help in-depth understanding of the current situation of PSS application under the guidance of CE, providing theoretical and practical guidance for related research.

MATERIALS AND METHOD

Literature resources

The primary source of literature is taken from Scopus. The database provides consistent and unified citation analysis records and resources with access to complete citation records and multiple sub-databases of scientific literature data, such as Conference Proceedings CitationIndex-Science (CPCI-S), Scopus Science Citation Index Expanded (SCI-E), and Social Sciences Citation Index (SSCI) (Singh et al., 2021). As a widely used peer-reviewed literature repository covering high-quality journals in multiple fields. Therefore, researchers can rely on the Scopus database to obtain literature information in related fields, understand the latest developments in the research field, main authors, citation trends, etc. This comprehensive coverage and reliabilitymakeScopusone of the essential sources for researchers to conduct bibliometric analysis (Lam & Habil, 2021).

Collection strategies

The search was done for this work on May 25, 2023 (Malaysian Time, 6:30 pm) to avoid changes due to the number of publications and citations. The search rule is Title-Abstract-Keywords = (circular economy OR recycling economy OR cyclic economy ORCE) AND (Product Service system OR PSS), which means circular economy and product service system included in abstract, title and keywords Publication records for terms, with a period set from 2014 to 2023.We excluded some literature types like Note, Erratum, and Data paper. A total of 763 documents were acquired and exported as "CSV Excel" for further bibliometric analysis and visualisation.

Statistical analysis

As a research method, bibliometrics analysis uses mathematics and statistics to conduct quantitative analysis of scientific research documents such as documents, papers, and journal articles. The VOS viewer bibliometric analysis software imports sample bibliographic data and draws network maps (Huang et al., 2022). Analysing relationships among publications, citations,co-citations, and keywords through powerful network visualisation, VOS viewer can map and display networks, revealing the structure of research fields (Van Eck & Waltman, 2017). It allows the researcher to explore the visualisation results independently and interactively, providing deeper insights (Puspitarini, 2023), enabling a better understanding of related fields' development trends and research direction.

RESULTS & DISCUSSIONS

Publication types and trends

The database analysis shows that, as shown in Table 1, there are eight main types of documents, among which the largest category is articles, accounting for 61.3% of the contribution,followed by conference papers, accounting for 17.6%, and the least is editorials, accounting for 0.3%. These data

reflect the distribution of different types of documents in the database,and articles and conference papers occupy a dominant position in the contribution rate, accounting for most of the proportion.

Table 1: General information on publications (2014-2023)

Rank	Type of Document	No.	Percentage
1	Article	468	61.3%
2	Conference Paper	134	17.6%
3	Review	70	9.2%
4	Book Chapter	58	7.6%
5	Conference Review	19	2.9%
6	Book	6	0.8%
7	Short Survey	3	0.4%
8	Editorial	2	0.3%
	Total	**763**	**100%**

Figure 1 shows that the last 10 years of research on PSS from a circular economy perspective has shown a growth trend, which, despite several ups and downs, still indicates a growing interest in the topic. There is an overall upward trend with respect to the number of citations, with the total number of citations peaks at 2953 in 2018 and then gradually declines. Due to the initial stage,the number of publications may be relatively small, which may take time to gain influence from accumulating new publications. Over time, as more research is conducted and published, the number of publications on the subject will likely increase rapidly, along with a gradual increase in citations. The circumstance also means that the topic has not yet reached its maturity stage and will still attract more research. It is worth noting that the number of publications and citations are only part of the measure of scientific productivity and influence, and the comprehensive consideration of other indicators and factors can more comprehensively assess the development and impact of a topic (Norouzi et al., 2021). In general, the research on product service systems from the perspective of the circular economy is booming, attracting more and more scholars' attention. Although some achievements have been made, further exploration and research still needed to promote widespread application of the concept of circular economy in practice.

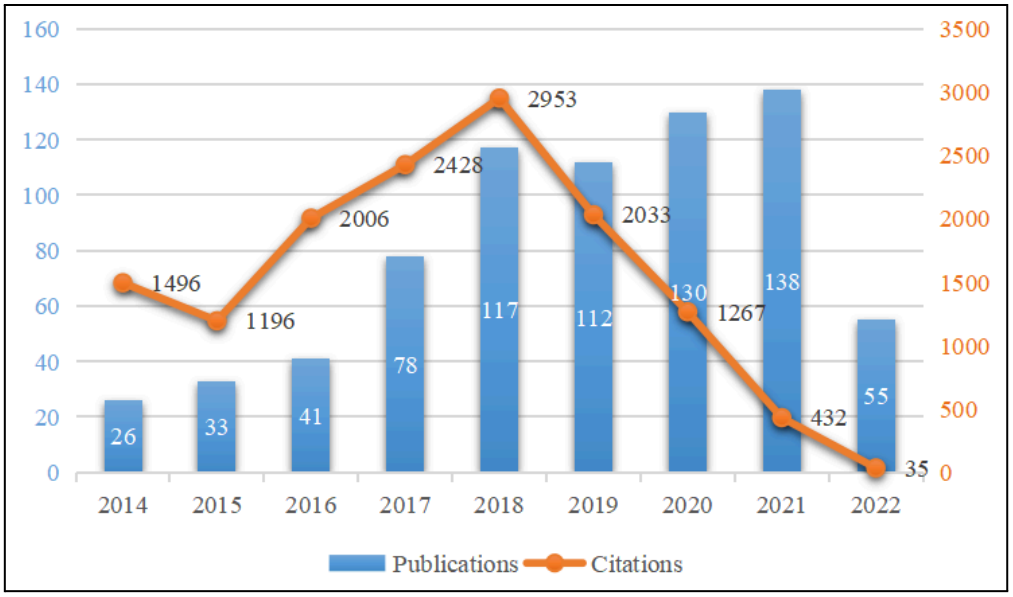

Figure 1. Changes in the number of publications and total citations (2014-2023)

Publication source distribution 763 articles published in various 159 journals. These journals are distributed in different fields of knowledge, such as Engineering, Environmental Science, Energy, Business, Management And Accounting, Social Sciences, Computer Science, etc. This shows that this topic has attracted the attention of a wide range of researchers as relevant research to promote environmental and economic development in other fields, involving multiple fields of knowledge. This shows that the product service system from the perspective of circular economy as a relevant research to promote environmental and economic development in other fields has become a research topic of interdisciplinary cooperation, and various fields have shown interest in this topic. This Study Summarises the 10 journals with the most publications on relevant topics, as shown in Table 2. Among them, "Sustainability" published the most 74 articles, this might be because the journal focuses on research in the fields of sustainable development and environmental protection, and the product service system oriented by circular economy has received extensive attention on important topics in this field. Followed by "Journal of Cleaner Production" (65), "Procedia CIRP" (43), "Resources Conservation and Recycling" (20), and "Sustainable Production and Consumption"(15 articles).

Table 2. Top 10 journals of publications (2014-2023)

Source Publication	No. of Publications
Sustainability	74
Journal of Cleaner Production	65
Procedia CIRP	43
Resources Conservation and Recycling	20
Sustainable Production and Consumption	15
Journal of Industrial Ecology	12
Journal Of Materials Chemistry C	9
Applied Sciences Switzerland	8
Business Strategy and The Environment	8
IFIP Advances in Information and Communication Technology	7

The Most Highly Cited Articles

Highly cited literature often represents classic or influential research in this field, and its analysis can help researchers gain an in-depth understanding of the significant research results, the knowledge base and the development of this field. Co-citation analysis was performed on the collected documents, and the minimum citation frequency was set to 100. A Total of 35 papers meeting the set requirements were screened out, and the top 10 highly cited papers on circular economy and product service systems from 2014 to 2023 were sorted out, as shown in Table 3. The most cited article is "Product Services for a resource-efficient and circular economy–a review" (Tukker, 2015), published in the Journal of Cleaner Production in 2015 with 1073 citations. This review article concludes by analysing the research literature in the field of PSS, summarising the development trends and critical issues of the past decade; this shows that this reviewarticlehasextensive academic influence and citation value in this field. The second article, "Current options for the valorisation of food manufacturing waste: a review" (Mirabella et al., 2014), was published in the Journal of Cleaner Production in 2014 and received 694 citations. This article discusses goodmanufacturing waste and current options for value-based processing, highlighting the application of industrial symbiosis in recycling food processing waste and presenting the main uses and application areas of waste conversion into valuable components. The third article, entitled "Circular business model innovation: inherent uncertainties" (Linder & Williamer, 2017), was published in Business strategy and the environment in 2017 and was cited 442 times. This article highlighted the uncertainties and challenges faced by circular economy business model innovation,and provided important theoretical and practical guidance for enterprises in the process of circular economy transformation. It is worth noting that among the ten highly cited papers, there are five review articles, which reflect that the comprehensive review and collation of this field has begun to be valued and provides a basis for further research.

Table 3. Top 10 highly cited papers (2014-2023)

No.	Author	Title	Journal	Year	Citation
1	Tukker, A.	Resource-efficient and circular economy–a review	Journal of Cleaner Production	2015	1073
2	Mirabella, N., Castellani, V., & Sala, S.	Current options for the valorisation of food manufacturing waste: a review.	Journal of Cleaner Production	2014	694
3	Linder, M., & Williander, M.	Circular business model innovation: inherent uncertainties.	Business Strategy and the Environment	2017	442
4	Witjes, S., & Lozano, R.	Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models	Resources, Conservation and Recycling	2016	371
5	Corona, B., Shen, L., Reike, D.,Carreón, J. R., & Worrell, E.	Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics.	Resources, Conservation and Recycling	2017	285
6	Bressanelli, G.,Adrodegari, F., Perona, M., & Saccani, N.	Exploring how usage-focused business models enable circular economy through digital technologies.	Sustainability	2018	277
7	Kristensen, H. S., & Mosgaard, M. A.	Reviewing literature on digitalisation, business model innovation, and sustainable industry: Past achievements and future promises	Journal of Cleaner Production	2020	273
7	Parida, V., Sjödin, D., & Reim, W.	Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: Making water tourism more sustainable.	Journal of Cleaner Production	2016	227
8	Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C.	The emergent role of digital technologies in the Circular Economy: A review.	Procedia CIRP	2017	226

Keywords analysis

Keywords represent the author's high-level summary of the research paper and are a concise way of expression. By analysing and organising key words in the literature, it can help researchers systematically understand the research trends in a specific field (Huang et al., 2022), help researchers grasp the current research hotspots in the area, and provide further insights into in this study, the author's keyword network diagram generated by VOS viewer software is used to analyse,in which each node represents a keyword. The lines between nodes represent the co-occurrence relationship between keywords resulting in frequently co-occurring keywords forming clusters, as shown in Figure 2. The keywords are divided into four clusters, respectively in the red, green, blue, and yellow clusters. In addition, the network graph also includes information about keyword frequency, which is very helpful for evaluating the importance and popularity of keywords in research. Keywords with higher frequency may be the core vocabulary of the

investigation,reflecting the importance of the topic in the literature and the degree of research attention,as shown in Table 4.

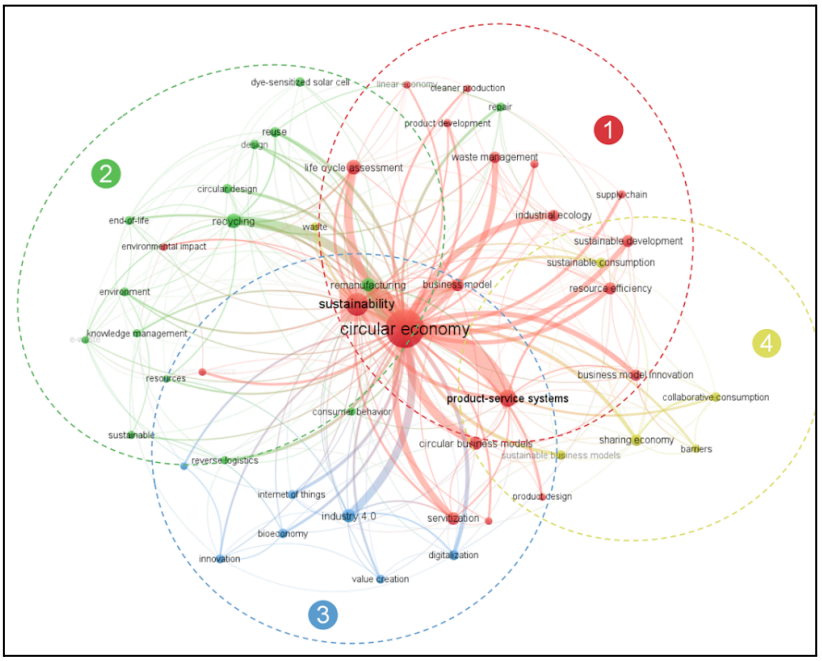

Figure 2. Keywords co-occurrence network (2014-2023)

Table 4. Keywords within the clusters

Cluster	Keywords
Business Mode	Business model (19), Business model innovation (14), Circular business models (21)
Red Cluster	Circular economy (356), Cleaner production (5), Environmental impact (5), Industrial ecology (14), Industrial symbiosis (6), Life cycle assessment (27), Linear economy (5), Product design (5), Product development (6), Product-service systems (42), Resource efficiency (15), System dynamics (5), Servitization (18), Supply chain (6), Supply chain management (5), Sustainability (90), Sustainable development (15), Waste management (14), Circular design (8), Consumer behaviour (6), Design (8), Dye-sensitized solar cell (8), E-waste (5), End-of-life (7), Environment (7), Knowledge management (6), Recycling (28), Remanufacturing (22), Repair (7), Resources (5), Reuse (11), Reverse logistics (6), Sustainable (6)
Green Cluster	Sustainability, Design & Waste Management: Bioeconomy (9), Digitalization (10), Industry 4.0 (22), Innovation (7), Internet of things (7), Renewable energy (5), Value creation (7)
Yellow Cluster	Sustainable Consumption & Collaborative Business Models: Barriers (6), Collaborative consumption (8), Sharing economy (13), Sustainable consumption (11), Sustainable Business Models (8), Waste (6)

Red cluster (cluster 1), these keywords reflect the core concepts, methods and concerns of the field of product-service systems and circular economy, covering business model innovation,resource efficiency, circular design, environmental impact, supply chain management, waste management etc. They play an important role in achieving sustainable development and solving environmental problems. When designing services, advocating circular economy principles isa key strategy that extends the life cycle of

products and services in the design domain. Through the practice of circular economy, resource consumption and waste generation can be reduced (Preist et al., 2016; Kjær et al., 2018), and waste can be transformed into valuable resources (Maiurova et al., 2022) to improve resource utilisation efficiency, thereby improving environmental conditions.

Green cluster (cluster 2), which reflects important issues and practices in product service systems and circular economy, can be derived from "design", "consumption behaviour", "recycling","remanufacturing", "reuse", "remediation", and other keywords to conclude. In the current context of strengthening environmental regulations and increasing economic viability, there is an increasing interest in product recovery and utilisation in the industrial sector (Fegade et al., 2015). Especially in the current economic environment, the dilemma many businesses face is not only on how to minimise and dispose of waste properly and convert waste into revenue-generating resources (Hatcher et al., 2013). The key to this transformation lies in the realisation of the concept of circular economy through the recycling and utilisation of waste, turning it into valuable resources, to realise the recycling of resources and the improvement of economic benefits (Ghisellini et al., 2016; Maiurova et al., 2022). Therefore, the industrial field is increasingly aware of the importance of recycling and utilisation and is actively seeking innovative solutions to promote sustainable development and environmental protection.

Blue cluster (cluster 3), these keywords relate to bio-economy, digital technology, industry 4.0, innovation, Internet of Things, renewable energy and value creation, etc., which are essential to developing product service systems and realising the sustainable economy's significance. Integrating these keywords into the design, production and delivery of products and services can promote economic transformation and innovation and achieve the goals of efficient use of resources and sustainable development.

The establishment of a product service system under the circular economy, combined with the application of new technologies, can promote innovation and value creation, such a digital technology and the support of the Internet of Things; enterprises can provide personalised products and services, and create new business models and value chains (He et al., 2020; Kamble et al., 2019), to help companies better understand consumer needs, adjust products and services in real-time, provide customised solutions, increase customer satisfaction and market competitive advantage. At the same time, adopting renewable energy can reduce dependence on traditional energy sources and reduce environmental impact (Hossein Motlagh et al., 2020; Nižetić et al., 2020). Using new technologies, companies can turn sustainability challenges into competitive advantages (Villiers et al., 2020), promoting corporate sustainability and commercial success.

Yellow cluster (cluster 4), these keywords relate to some critical issues and challenges developing product-service systems, including transforming consumption patterns, resource sharing and recycling, realising sustainable business model development goals, etc. In The Circular Economy context, these issues become more urgent and vital. As an emerging business model, PSS has the potential to promote product life extension and recycling (Pieroni et al., 2019) and plays an important role in promoting the development of a circular economy, realising the effective use of resources and reducing environmental impact. However, implementing PSS also faces some challenges, which need to overcome barriers, collaborative consumption (Retamal, 2019) and sharing economy (Plewnia & Guenther, 2018), promote sustainable consumption and business models, and reduce waste generation, promote product services the system movie s in a more sustainable direction.

While 49 keywords appeared most frequently (more than five occurrences) in this study,the circular keyword economy appeared 356 times in publications, followed by sustainability (90) and product service systems (42). The overlay visualisation of the keyword co-occurrence network shown in Figure 3. It recently appeared in the research of product-service systems under the guidance of the circular

economy. It is an emerging research direction and has become a significant topic in the contemporary economic and social fields. The research areas are detailed below as potential research hotspots.

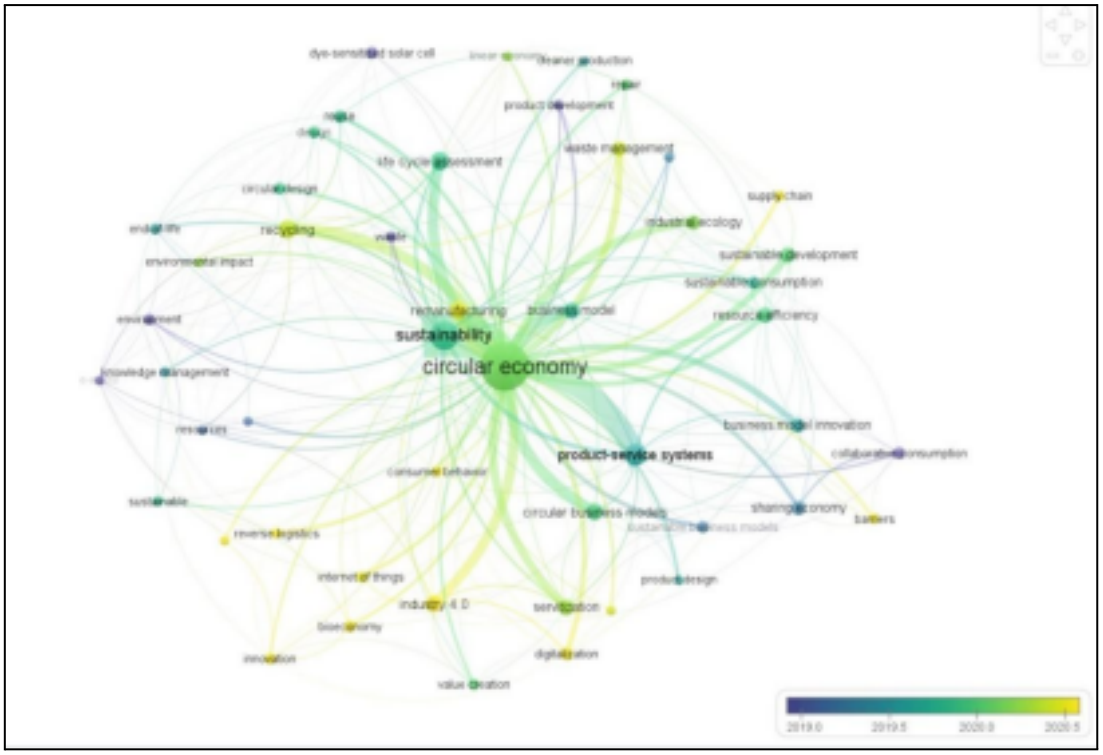

Figure 3. Research hotspots co-occurrence map density (2014-2023)

The application of product-service systems on the Internet of Things research under the guidance of circular economy is one of the frontiers of current literature research. With the rise of the concept of circular economy and the importance of sustainable development, combining the principles of circular economy with Internet of Things technology to provide more sustainable solutions through the integration of products and services has become a research hotspot (Voulgaridis et al., 2022). The circular economy-oriented product-service system aims to maximise the use of resources and reduce waste generation by transforming product provisioning service-centric models (Heyes et al., 2018; Witjes & Lozano, 2016). The Internet of Things technology plays a key role in it. Through the connection of physical devices and sensors, remote monitoring,data collection, and analysis of products can be realised (Tao & Qi, 2017). In this way, product usage efficiency can be optimised, and product life can be extended. life cycle (Herterich et al., 2015).

Another hot topic is research in Industry 4.0. Industry 4.0 focuses on digitisation,automation, and intelligence, integrates physical and digital systems (Zhou et al., 2015), and realises the optimisation and intelligence of the production process through technologies such as the Internet of Things, big data analysis, and artificial intelligence. The product service system under the guidance of the circular economy is in line with the concept of Industry 4.0. By Integrating the principles of circular economy and Industry 4.0 technology, the efficient use of resources, the reduction of waste and the management of the product life cycle can be realised (Nascimento et al., 2019). This is not only in line with the concept of sustainable development,but also helps to improve the production efficiency and competitiveness of enterprises. In the future, the combination of a circular economy and Industry 4.0 will become an important means to promote industrial development and environmental protection (Nascimento et al., 2018); (Bai et al., 2022).

Another research focus is the study of consumer behaviour, which explores consumer acceptance, attitudes and behaviours towards sustainable products and services. Withchangesinsocial and economic environments, consumer behaviours are also evolving (LAL, 2012), such as the rise of sustainable development and circular economy, which raise new issues and challenges for consumer behaviour research. The traditional linear economic model emphasises one-time consumption and waste of products, while the product service system guided by circular economy emphasises the continuous use and recycling of products. By providing a product-oriented, usage-oriented and result-oriented service model (Tukker, 2004), consumers can enjoy the product's functions and services without owning the product's ownership (Beuren et al., 2013). This transformation can meet consumers' needs for functions and experiences and align with their sustainable development and environmental protection values.

The last featured topic has important applications in reverse logistics research. It involves product recycling, remanufacturing, reverse supply chain management, etc. (Julianelli et al., 2020). Although reverse logistics burdens the company, it can contribute to its finances (Larsen et al., 2018). At the same time, it can establish a long-term cooperative relationship between customers and the company (Jayaraman & Luo, 2007), and the company can recycle used products and remanufacture, prolonging product life, reducing resource consumption and waste generation (Khor et al., 2016).

CONCLUSION

In this study, the bibliometric approach was adopted to analyse 763 publications the application of product-service systems under circular economy orientation from 2014 to 2023.Therecords extracted from Scopus were integrated and conducted as an in-depth analysis with VOS viewer. A comprehensive understanding was gained of the research status and development trends on product-service systems within the field of the circular economy.

According to the analysis findings, there is an ongoing upward trajectory in the number of publications, indicating a sustained growth pattern. This rapid acceleration demonstrates the increasing prominence of product-service systems implemented within the circular economy framework. This area of focus is gaining significant attention. The primary scholarly sources that prominently contribute to this field include "Sustainability", "Journal of Cleaner Production", and "Procedia CIRP", which rank among the top three publications. The articles with the highest number of citations are "Product Services for a Resource-efficient and circular economy–a review," "Current Options for the Valorisation of food manufacturing waste: a review," and"Circular Business model innovation: inherent uncertainties." These publications have received significant attention and recognition in terms of citation count. In terms of keyword analysis, the primary research topics predominantly revolve around circular economy, sustainability, and product service systems. Notably, the research hotspots include the Internet of Things, Industry 4.0, consumer behaviour, and reverse logistics. These areas have garnered substantial interest and attention among researchers. Through this study, we hope to provide researchers and policymakers in the field of circular economy with a comprehensive understanding of the application of PSS in the circular economy. At the same time, we can also discover research hotspots and potential development directions in this field, providing reference and guidance for future research.

Finally, it is acknowledged that this study has certain limitations. Firstly, the study only used one database to retrieve information and did not include publications outside the Scopus Database, possibly excluding some influential articles. Furthermore, a subset of the retrieveddocumentsexhibits a relatively tenuous connection to the field of product service system application within the circular economy framework. In addition, the manual screening process has a certain degree of subjectivity. Therefore, future research should utilise multiple databases to search publications and apply text data mining tools to

filter the results to improve the accuracy of the analysis. Overall,despite the limitations, the bibliometric analysis can still provide compelling evidence of discernible and promising research trends in the field of product service system application within the circular economy framework.

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