Bibliometric Analysis of Product-Service System Related to Life Cycle

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Keywords: Bibliometric Analysis, Life Cycle, Product-Service System, Sustainability.

Abstract: The product-service system (PSS) concept is a concept that offers an alternative consumption pattern by shifting the consumption of tangible products into one product and service bundle. This concept appears to address the sustainability problem. In a company, the PSS concept is closely related firm life cycle. This paper aims to provide an overview of the bibliometric literature on PSS in terms of the life cycle. The methodology used is a bibliometric literature review and article mapping using VOSviewer software. The articles studied Scopus indexed articles, found on scopus.com based on the keywords 'product-service system' and 'life cycle'. From the results of the research conducted, it can be concluded that the articles were originally in the field of product development as well as product and service developed towards industrial management and competitive advantage. This study provides an appropriate basis for further research and a research road map on 'product service systems' related to 'life cycles'. By mapping the bibliometric, researchers can find out what areas need to be further developed. Further research can be conducted with recent articles to always track the dynamics of the research related.

1 INTRODUCTION

Nowadays, human consumption patterns can be divided into 2 groups, namely overconsumption and under consumption (Mont, 2002). Both groups are burdensome to the environment. Overconsumption, usually done by the prosperous people, namely the pattern of consumption of goods more than what is needed (Mont, 2002) so that it wastes existing resources. Meanwhile, under-consumption is usually carried out by underprivileged people, who exploit natural resources unwise and cause damage to the environment (Mont, 2002).

As the human population continues to increase, if these two patterns are ignored, in the next few decades it will result in a lack of productivity. This deficiency occurs due to the use of large amounts of energy and materials for making tangible goods, which are natural resources. This condition threatening sustainability. However, since the early 1980s, people have started to aware of sustainability. Sustainability is viewed from three aspects, namely economic, environmental and social (Elkington, 2004). With this awareness of sustainability, there needs to be a breakthrough that can save resource consumption.

A strategy that can be implemented to save resource consumption is the concept of a product-service system (PSS). This concept offers a change in consumption patterns from tangible goods (products) to packages consisting of tangible goods (products) and services (services) (Goedkoop, Halen, Riele, & Rommens, 1999; Mont, 2002). In this concept, the consumption of tangible goods is shifted to services wherever possible without sacrificing the performance and benefits provided to customers (Baines et al., 2007; Mont, 2002; Tukker, 2004). Implementing PSS can decrease the consumption of tangible goods, protect the environmental burden, and offer the entrepreneur a new business model. Thus, PSS can encourage sustainability.

In the context of maintaining sustainability, PSS needs to be linked to the life cycle. PSS can be used to manage life cycles by varying the bundle of products and services and shift to more services. Then in turn it is helping to extend sustainability as well.

Until now, research on PSS has been done by many researcher (such as Baines et al., 2007; Goedkoop et al., 1999; Mont, 2002; Tukker, 2004 and

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Wirawan, C.
Bibliometric Analysis of Product-Service System Related to Life Cycle.
DOI: 10.5220/0010745000003112
In *Proceedings of the 1st International Conference on Emerging Issues in Humanity Studies and Social Sciences (ICE-HUMS 2021)*, pages 110-118
ISBN: 978-989-758-604-0
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many more). Research on PSS is increasing over time in terms of quantity and from related areas. The life cycle concept also a mature concept and applied to product (Hill, Jones, & Schilling, 2015; Cao & Folan, 2012), industry (Karniouchina, Carson, Short, & Ketchen, 2013; Tavassoli, 2015), organization or company (Jawahar & McLaughlin, 2001; Hasan, 2018; Bakarich, Hossain, & Weintrop, 2019).

In addition, there are many articles relating PSS to the life cycle. Several articles related PSS with product life cycle design (such as Doualle et al., 2016; Mourtzis, Doukas, & Fotia, 2016; Haber, Fargnolli and Sakao, 2016; etc.), product life cycle management and improvement (such as Lindkvist & Sundin, 2016; Patala et al., 2016; Kambanou, 2020; etc.), PSS life cycle engineering (such as Berkovich, Krcmar, & Leimester, 2011; Sousa-Zomer, Magalhae, Zancul, & Cauchick-Miguel, 2017; Zhang, Ming, & Yin, 2020; etc.), PSS life cycle assessment (Kambanou, & Lindahl, 2016; Banerjee, & Punekar, 2020; Bonilla-Alicea et al., 2020; etc), and PSS life cycle customer needs (Annarelli, Battistella, & Nonino, 2020; Kim, 2020; Liu et al., 2020; etc.) and many more. With the variety of research areas regarding PSS related to the life cycle, it is necessary to have a study that shows the conditions of these studies. This research will be useful for researchers who will continue or seek new fields related to the PSS area and the life cycle.

But an article about bibliometric and map generated to describes the position of existing articles related to PSS and life cycle not found. The bibliometric analysis had not been found for PSS areas, even more related to life cycle area. Therefore, this article aims to fill in the research gap by providing an extensive bibliometric analysis of the PSS related to life cycle literature. Bibliometric analysis conducted based on articles published and indexed by Scopus using VOSviewer software.

This article benefit researcher to view the map of the current articles related to PSS and life cycle and find further research. Further research hopefully can develop the area of PSS and life cycle which can encourage sustainability.

2 METHODS (AND MATERIALS)

Related to the background, the research questions are: What is the current map of Scopus indexed articles related to PSS and the life cycle? What areas are related to PSS and the life cycle that has developed a lot and which are not yet? Then, what research opportunities could be undertaken to fill in the gaps and develop this area.

This article conducted the bibliometric study by mapping and analysing scientific articles that have been published or in press. The topic to be mapped and analysed in this study is PSS related to life cycles. The method used in this research is a five-stage method (Hudha et al., 2020) as shown in Figure 1.

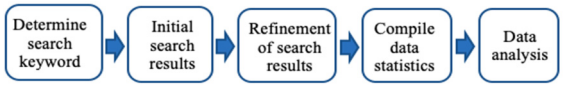

Figure 1: Bibliometric analysis steps (Hudha et al., 2020).

As at figure 1, following are the explanation about each step.

1 Determine Search Keyword

This is the first step of the research. In this step, I use the source of the articles analysed and the keyword used to search the articles. To ensure good quality articles that analysed, the articles search from the scopus.com website.

The keyword used is related to PSS and the life cycle. Then, the literature search was conducted on 17 November 2020 at the scopus.com website, using TITLE-ABS-KEY (“product-service system” OR “product service system” OR “PSS”) AND TITLE-ABS-KEY (“life cycle” OR “life-cycle”) keyword.

2 Initial Search Results

As mentioned before, literature search were Scopus indexed articles. It is found that the articles range from the year 2001 to 2021. At first search, 626 articles found. Then, I go to the next step, refinement of search results.

3 Refinement of Search Results

To improve the results, the refinement of the search conducted. The refinement is done by excluding:

- Non-English articles
- Review and conference review type articles
- Unrelated area: agriculture and biological science, chemical, biochemical, medicine, nursing, pharmacology, toxicology and pharmaceutical, earth and planetary science, physic and astronomy, chemical engineering and health professions
- Lecture notes
- Retracted article

After the refinement, there are 503 articles left for further analysis. The results are saved in Research Information Systems (RIS) format including article’s titles, authors, authors’ affiliations, keywords, abstracts, and citations for further analysis.

4 Compile Data Statistics

The data of the articles collected from the refinement of search results steps, then converted to Microsoft Excel, while checked for the completeness and accuracy of the information. If necessary, data from google scholar also added to improve the database. The data tabulated and analysed to find the spread according to the year of publication, citation number, and articles number per journal or proceeding.

5 Data Analysis

The bibliometric analysis in this study employed descriptive statistical. However, to analyse and visualise bibliometric networks, VOSviewer software is used (Martínez-López, Merigó, Gázquez-Abad, & Ruiz-Real, 2020; Shukla, Merigó, Lammers, & Miranda, 2020). VOSviewer also help to create publication maps, author maps, or journal maps based on co-citation networks or to build keyword maps based on shared networks (Hudha et al., 2020).

3 RESULTS AND DISCUSSION

Based on the data collected and analysed, we found the results and following we discussed the results.

3.1 Publications and Citations Structure

The statistical analysis results of the articles discussed PSS related to life cycle are shown at table 1 to table 4 and figure 2.

Table 1: Data of articles related to PSS and Life Cycle indexed by Scopus.

DATA	SEARCH RESULTS
Source	scopus.com
Keywords	"product service system" AND "life cycle"
Year	2001-2021
Number of paper	503
Total citation	7375
Average citation per year	351.2
Average citation per article	14.7
Average author number per article	3.5

As can be seen in Table 1, we found that the first publication indexed by Scopus about PSS related to life cycle is at 2001 in total 3 publications, while publication not indexed by Scopus found at 1999 (Goedkoop et al., 1999). From Table 1. it can be seen that from 2001-2021 there were 503 articles published in Scopus indexed documents (book, book chapter, journal and proceeding) discussing PSS related to life cycles. For articles in 2021 are still in-press status and there are 2 articles recorded. Of these 503 articles, the average citation per article quite high reaches 14.7 citations and an average number of citations 351.2 per year. This information indicates that these articles are of high quality and that the science in this field is produced and developed during these periods. So that, it can be concluded that the discussion of this area is suitable.

Table 2 and figure 2 show the distribution of articles published yearly for each type of publications. Most of the publications are in the form of proceedings, shown that many conferences held related to the topic. This indicated that this topic could interest the authors.

Table 2: Number of publications spread by year of publication and type.

Year	Type				
	Book	Book Chapter	Journal	Proceedings	Total
2001			2	1	3
2002			1	1	2
2003			3		3
2004		1			1
2005	1	1		3	5
2006			6	9	15
2007		1	3	8	12
2008			1	6	7
2009		3	10	3	16
2010			2	8	10
2011			9	11	20
2012			5	11	16
2013		8	4	23	35
2014			8	21	29
2015	1	2	5	23	31
2016		1	11	84	96
2017	1	4	15	40	60
2018			24	32	56
2019		2	16	33	51
2020			22	11	33
2021			2		2
Total	3	23	149	328	503

The topic of PSS is relatively new because it only started around 1999, so it can be seen that in the early 2000s there were still few articles published but there is an increasing trend. Started in 2006 the number was incrementally increased and was quite stable until it experienced a sharp increase in 2013 and a spike occurred in 2016.

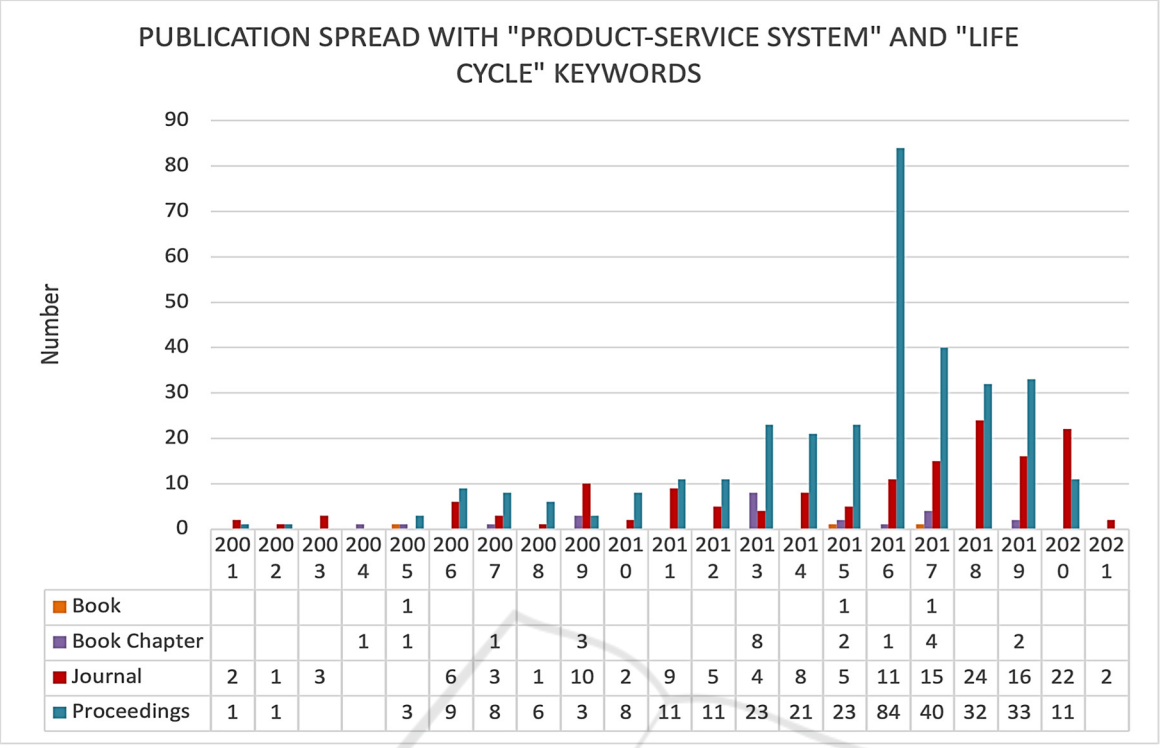

Figure 2: Publication distribution diagram by year and type of publication.

Table 3: Top ten cited articles.

No.	Year of Publication	Authors	Title	Journal/Proceeding	Number of Citation	Volume Issue	Page
1	2006	Aurich, J.C., Fuchs, C., Wagenknecht, C.	Life cycle oriented design of technical Product-Service Systems	Journal of Cleaner Production	426	14(17)	1480-1494
2	2003	Maxwell, D., Van Der Vorst, R.	Developing sustainable products and services	Journal of Cleaner Production	330	11(8)	883-895
3	2007	Williams, A.	Product service systems in the automobile industry: contribution to system innovation?	Journal of Cleaner Production	157	15(11-12)	1093-1103
4	2006	Maxwell, D., Sheate, W., Van Der Vorst, R.	Functional and systems aspects of the sustainable product and service development approach for industry	Journal of Cleaner Production	156	14(17)	1466-1479
5	2014	Lindahl, M., Sundin, E., Sakao, T.	Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases	Journal of Cleaner Production	147	64	288-296
6	2009	Isaksson, O., Larsson, T.C., Ronnback, O.	Development of product-service systems: Challenges and opportunities for the manufacturing firm	Journal of Engineering Design	141	20(4)	329-348
7	2015	Lerch, C., Gotsch, M.	Digitalized product-service systems in manufacturing firms : A case study analysis	Research Technology Management	130	58(5)	42-52
8	2009	Sundin, E., Lindahl, M., Ijomah, W.	Product design for product/service systems: Design experiences from Swedish industry	Journal of Manufacturing Technology Management	126	20(5)	723-753
9	2002	Vogtländer, J. G., Brezet, H.C., Hendriks, C.F.	Communicating the eco-efficiency of products and services by means of the eco-costs/value model	Journal of Cleaner Production	123	10(1)	57-67
10	2015	Herterich, M.M., Uebernickel, F., Brenner, W.	The impact of cyber-physical systems on industrial services in manufacturing	Procedia CIRP	118	30	323-328

This surge most of the proceedings, with the implementation of quite some conferences on this topic in 2016. In 2017 the articles decreased when compared to the spike in 2016, but when compared to 2015 it increased and tended to be stable until 2019. Even though in 2017 the number of articles decreased, However, the number of articles in journals is increasing because there have been many studies and writings that have solidified experts for publication in journals. For 2020 proceedings

decreased drastically, due to the Covid-19 pandemic which prevented the conference from being held. Another cause could also be a pandemic hindering the conduct of research, so the completion schedule was postponed. In addition, the Covid pandemic has also affected the speed and time accuracy of journal publishing.

Another explanation about the decreasing amount of publications in the development of the PSS area was going to other many areas besides the life cycle so that the research and articles spreading to many areas.

The most cited articles are shown in table 3. These articles can be considered as "key articles" in the field of PSS related to life cycles. They should be had a good quality as well as high novelty so that many other researchers have cited them. By knowing this information, these articles can be taken into consideration to read earlier if the researcher wants to study PSS related to life cycles.

Next is information about journals and proceedings that mostly publish PSS articles related to life cycles as in table 4. In this table, it can be seen that Procedia CIRP contains the largest number of articles related to the topic of PSS and life cycles, followed by the Journal of Cleaner Production. This information can be a reference for researchers who want to find or publish their work with appropriate topics.

Table 4: Top journals or proceedings published articles under PSS related to life cycle area.

No.	Journal	Articles	Citation
1	Procedia CIRP	154	1199
2	Journal of Cleaner Production	33	2412
3	IFIP Advances in Information and Communication Technology	30	145
4	Proceedings of the International Conference on Engineering Design, ICED	15	25
5	Sustainability (Switzerland)	12	133
6	CIRP Annals - Manufacturing Technology	11	250
7	International Journal of Production Research	8	328
8	IFAC-PapersOnLine	7	47

3.2 VOSviewer Mapping Results based on Topic Areas

The database of articles analysed using VOSviewer software. The articles downloaded from scopus.com stored at RIS files. The RIS file is then uploaded to VOSviewer with the following steps: Create - Create a map based on bibliography data - Read data from reference manager file - RIS, select the file - Type analysis: co-occurrence - Counting method: full counting - Next – Next.

After done these steps, VOSviewer shown the keywords detected by VOSviewer. The next step is to observe keywords. If there are keywords that have a similar mean, then the keywords are combined with the help of a thesaurus file. Thesaurus file can be generated by making two column file, label and replaced by, then convert the file to txt file. Furthermore, some general or irrelevant keywords are excluded. In this study, the keywords "3d printers", "article" and "priority journal" were excluded.

Visualization generated by VOSviewer can be seen in figure 3. This figure shows the relationship

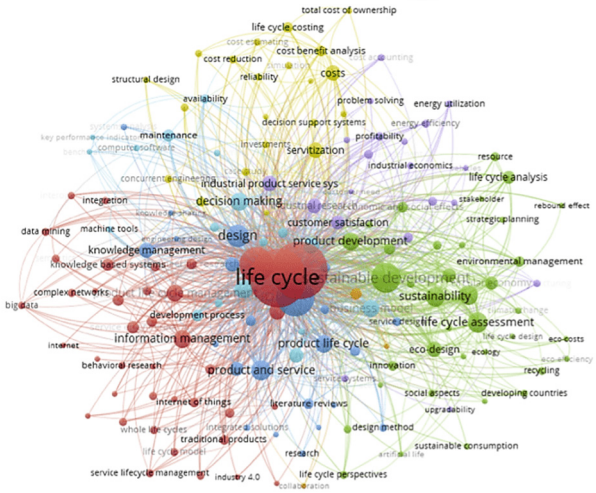

Figure 3: Map of articles related to life cycle and PSS.

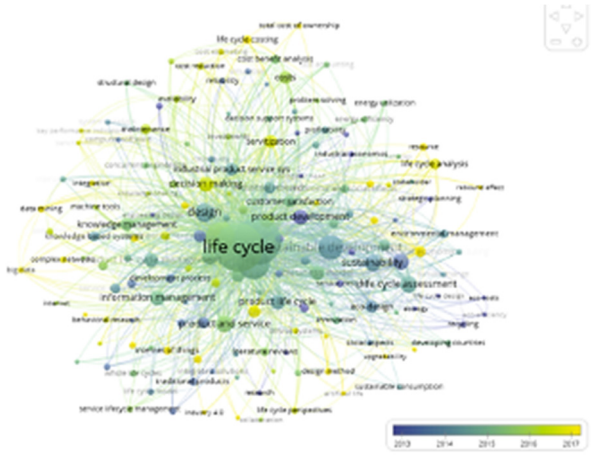

Figure 4: Overlay visualization.

Figure 5: Distribution and relationship of authors for PSS related to life cycle.

keywords, described by lines. The circle size represented the amounts of articles find. The small circle represented keywords with the small number of articles found. On the contrary, a big circle represented keywords with the large number of articles found. The two biggest circles related to PSS and life cycle are product development and design.

The figure also shows clusters formed, represented with different colours. In this picture, the keywords are divided into 7 clusters, represented by each colour. Each cluster, represented keywords that usually used together in articles. The cluster elements formed can be seen in table 5. From table 5, we can find each cluster's topics describe topics that usually related to research by the researcher.

Figure 4. shows a similar map to figure 3, but in this figure, the map shows the years of publication is due. This map shows the history of the emergence of this topic and then its development into other topics. By knowing this distribution, researcher can trace the origin of topics and can also search for the latest topics.

Figure 5 shows the distribution of authors and their relation to other authors. This description helps future researchers to find key authors in related topics. This knowledge help author to trace the articles and find the thought of the authors to ease future researchers to compare the thoughts and find novelties.

Figure 6 shows the distribution of authors calculated from the time of publication. This map helped researchers to trace the author's activity and the history of their thoughts. This knowledge help researchers to follow the thoughts then find their own.

4 CONCLUSIONS

From the results of research conducted, it can be concluded that articles published and indexed by

Table 5: Cluster elements formed.

No.	Cluster	Elemen
1	Cluster 1 (red)	Agile manufacturing system, automotive industry, behavioral research, big data, complex network, cyber physical system, data mining, embedded systems, engineering research, enterprise resources planning, industrial case studies, industrial management, industry 4.0, information management, information systems, integration, internet, internet of things, interoperability, knowledge based system, life cycle, life cycle management, life cycle model, manufacture, ontology, physical product, product life cycle management, product-service system, product-service system, pss life cycle, quality function deployment, requirements engineering, semantics, service engineering, service life, service life cycle management, smart products, systems engineering, traditional products, virtual corporation, whole life cyle
2	Cluster 2 (green)	Artificial life, circular economy, climate change, commerce, developing countries, eco-costs, eco-design, eco-efficiency, ecology, economic and social efficiency, economics, ecosystem, electronic waste, environmental impact, environmental management, environmental performance, environmental technology, innovation, life cycle analysis, life cycle assessment, life cycle design, life cycle perspective, new business models, product development, rebound effect, recycling, source, social aspects, stakeholder, strategic planning, sustainability, sustainability assessment, sustainable consumption, sustainable development, sustainable product-service, sustainable production, sustainable products
3	Cluster 3 (blue)	Design, design for x, design method, design strategies, engineering design, industry, integrated products, integrated solutions, knowledge management, knowledge-sharing, literature reviews, management, personalizations, planning, product and service, product design, product life cycle, pss design, research, service, service design, system analysis
4	Cluster 4 (yellow)	Case study, computer aided design, concurrent engineering, cost benefit analysis, cost engineering, cost estimating, cost reduction, costs, decision support system, investments, life cycle costing, reliability, repair, risk management, servitization, simulation, structural design, tools, total cost of ownership, transformation, uncertainty analysis
5	Cluster 5 (purple)	Conceptual design, conceptual framework, cost accounting, customer need, customer satisfaction, energy efficiency, energy utilization, industrial economics, industrial product, industrial product service, industrial research, obsolence, optimization, problem solving, profitability, remanufacturing, service systems, supply chain management, upgradeability, vehicles
6	Cluster 6 (cyan)	Availability, benchmarking, business model, business modelling, competition, competitive advantage, computer software, customer requirement, decision making, development process, information and communication, key performance indicator, machine tools, machinery, maintenance, sales, technical products, value creation
7	Cluster 7 (orange)	Collaboration, future research directions, supply chains

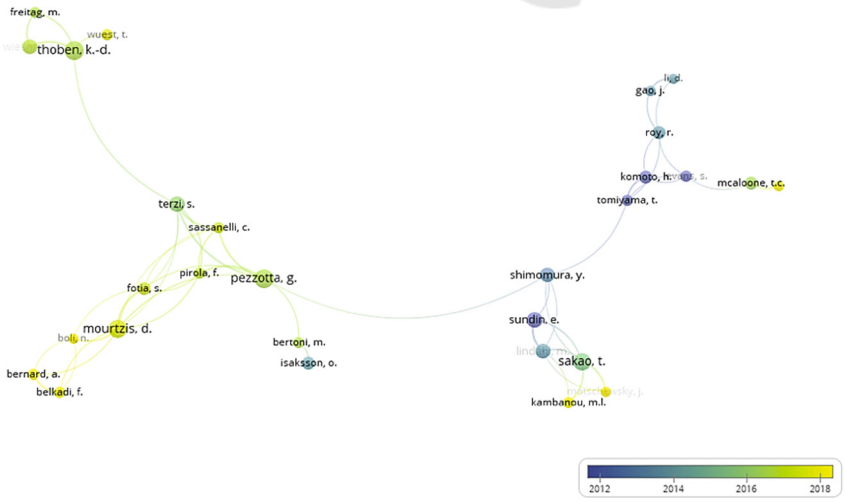

Figure 6: Distribution and relationship of authors for PSS related to life cycle by years.

Scopus from 2001-2021 with the topic "product-service system" and "life cycle" have been found. From the year the article was published, it can be seen, in general, the initial topic was about product development and product and service that developed towards industrial management and competitive advantage. Then the environmental impact develops on the other hand, which develops into sustainability and sustainable development.

After that, interrelated and emerged PSS, life cycle, decision making which then evolved into life cycle management, cost, and maintenance. The topics that were then raised were life cycle costing, business models, big data, IoT, industry 4.0 and quality function deployment. The last topics are topics that are still a little-publicized so that they still open up opportunities for further researcher.

Other topics that people have written about the life cycle and PSS for a long time also still have the opportunity to be researched, considering that the circle is not too big and has something to do with the life cycle and PSS. Other research opportunities can also be searched by linking topics that are not currently related.

Further, this article can be used by researchers as a base to do a literature review, state of the art, as well as to find novelties and research ideas. To keep on up to date, this article needs to be upgraded periodically due to the fast addition articles at scopus.com.

The limitation of this research is that it only takes data from scopus.com because it wants to make sure the articles analysed are good articles. But actually, there are other articles that are not included in Scopus.com, for example on the Web of Knowledge, Google Scholar, and others. Therefore, for future research, articles from more sources can be taken.

Another thing that is also a limitation is that this bibliometric analysis is carried out in 2020, so it takes data on articles that have been published or will be published until November 17, 2020. Meanwhile, the articles published will definitely continue to grow over time, so bibliometric analysis is also necessary. constantly updated to get the latest condition maps. There will always be opportunities for future research to carry out bibliometric analysis.

In addition, this study only discusses research areas related to PSS and the life cycle. Future research can be done by discussing other topics related to PSS, such as sustainability, product design, big data, and others.

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