

7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business

Bibliometric Analysis of the Product-Service System Research Field

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Abstract

The interest for the product-service system (PSS) approach has increased substantially in the last decade. New born research fields such as the PSS require the understanding of their knowledge structure as well as of their evolving structure of research collaborations. In this sense, the research field is better explained, supporting the alignment among new studies and an improved performance in the knowledge building. There are already papers in the literature that addressed the state-of-the-art in PSS, providing important guidance. However, they have not still focused on quantitative metrics, which are capable of providing a supplementary perspective. Therefore, this study aims at developing a bibliometric analysis of the PSS research field, looking for its current situation and possible evolution in terms of knowledge creation, collaboration networks and geographical distribution. A sample of 118 PSS papers published from 2002 to 2013 was collected in the Web of Science Database. Vantage Point, UCINET and NetDraw software was used to perform the bibliometric analysis. The results show a huge increase of the research field after 2011 and a balanced distribution of papers among authors. Europe and Asia are assigned to the majority of studies, showing strong collaboration networks among their institutions. Furthermore, journals with the highest number of PSS papers and the most cited papers are identified as well as the predominant knowledge topics addressed within the period. This study provides a holistic view of the PSS research field. It provides metrics regarding publications, which are useful for new entrants to identify the state-of-the-art and to understand their possible contributions to the research field. In addition, the investigation of collaboration networks shows the research groups in activity, highlighting opportunities for new collaborations and supporting the development of scientific policies. Finally, this study adopts quantitative metrics that can be reused for other studies in the future to update the status of the PSS research field or to perform similar analysis for other fields.

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1. Introduction

The product-service system (PSS) has emerged as one of the most important business options for the future of the industrial organizations. PSS consists of a new business concept in which organizations shift their focus from delivering physical products to solutions combining physical products with services that are capable of fulfilling customers' needs and reducing environmental impact [1, 2].

PSS studies include subjects related to servitization and service-dominant logic. These terms consider an important trend of modern economy, related to the predominance of

service organizations in developed countries [3]. This fact has motivated producers of physical goods to look for opportunities of aggregating services to their products. As a result of the potential advantages of employing PSS, the interest in using it has grown quickly among practitioners and academics.

PSS as such can be considered a new research field. The first scientific paper dealing with PSS indexed in the Web of Science database was published in 2002, in spite of the existence of PSS publications dated before this year, which were not indexed in this important scientific repository. Since then, many papers have been published, contributing to the

growth of the PSS body of knowledge. However, as a new research field, it requires an in depth analysis of the state-of-the-art, aiming at clarifying what has been already investigated and what will need further investigation to support a systematic development of new knowledge. Furthermore, research centers and collaboration networks are also in formation, once new researchers are entering the area and selecting their topics of interest and potential partners.

There are already literature reviews that provided important guidance about fundamental concepts, research lines and requirements for future research. Tukker and Tischner [4] drew attention to the importance of improving the scientific rigor in terms of revisiting existing theories related to PSS field, such as business management and research method. Baines et al [5] developed a comprehensive analysis of the state-of-the-art in PSS and provided a list of findings. For example, they also stated that the existent PSS methodologies are largely founded on conventional processes, lacking the development required to introduce a complete product-service system. Lightfoot et al. [6] identified the main research communities dealing with PSS theories and described their main characteristics and contributions. Beuren et al [7] proposed an update of the Baines et al. [5]'s study by including publications from 2006 to 2010. As a result, they reinforced the importance of addressing stakeholders, property transfer, analysis of consumer behaviour and of providing service experience based on the research presented by Geum and Park [8]. Boehm and Thomas [9] conducted a systematic literature review focused on three knowledge fields which have been contributed with PSS theories: information system, business management and engineering and design. These authors claimed that although there were literature reviews on PSS, they were not clear and systematic, undertaking qualitative approaches in most of times. Demirkan et al. [10] argue about the relationship between the business and technological aspects, which seems relevant for the PSS field.

Based on the aforementioned papers, this study identified an opportunity to investigate PSS using quantitative metrics, which are capable of providing a supplementary perspective of the evolution of the research field over the last years. Therefore, this study aims at developing a bibliometric analysis of the PSS research field, looking for its current situation and possible evolution in terms of knowledge creation, collaboration networks and geographical distribution.

2. Methodology

A systematic literature review provides an understanding of the current knowledge based on scientific publications, leading to the identification and description of the state-of-the-art about a selected subject as well as underpinning the proposal and development of new researches [11, 12]. Bibliometric analyses are often conducted as an essential part of systematic review, since they clarify information concerning the progress of knowledge creation based on quantitative metrics of scientific production. The implementation of bibliometric analyses are linked to the current potential of scientific databases, whose technological

advance have permitted registering and controlling of worldwide scientific production.

The source of information chosen for this study was the ISI Web of Science. This scientific database embraces the core academic journals related to the subject of interest, and it also has a thorough and structured description of its indexed papers, which is essential to perform bibliometric analyses. The search conducted in Web of Science covered papers published from 2002 to 2013 whose title or abstract included the following keywords: "product service system" or "servitization". As a result of this search string, 131 papers were identified. It should be noted that conference papers were not considered in this study.

Once the sample of 131 papers was established, the first step of the review process consisted of checking in the title and abstract whether the papers in the sample were in fact about product-service system. This verification was performed through a double-check process involving two researches. At the end, 13 papers were removed, resulting in a final sample of 118 journal papers concerning product-service system. It is noteworthy that this number is superior, considering only the Web of Science database, to those presented by other works, especially Beuren et al [7]. This might be explained by the date of data collection or by the terms used in the search or by the combination of terms employed. It is impossible to present the full list (appendix) with these articles due the page limitation.

The next step of the study was applying the bibliometric analysis. To this end, the VantagePoint bibliometric software was employed. It is a tool that supports a comprehensive and effective compilation of papers' metadata, generating data required for histograms, charts and network analyses. When network analyses were required, UCINET software was used to compile network data and NetDraw software used to plot network charts. The following analyses were performed in this study: number of papers per year, number of papers per author, number of papers per institution, number of papers per journals, the most used keywords, the most cited papers and the most cited references. In addition, the following networks were built: co-authorship network, institutional network, keywords network and co-citation network. The main function of these networks is checking the relationship characteristics among interconnected groups. For example, central nodes in a co-citation network indicates papers often used as reference in a research field. It should be noted that thresholds were applied in the development of these analyses and networks in order to assure that essential information could be properly presented. Finally, results provided were interpreted and underpinned the description of knowledge creation, knowledge distribution and research collaboration for the product-service system field.

3. Bibliometric Results

3.1. Number of papers per year

Fig. 1 illustrates the distribution of the 118 papers over the years. It can be noted that the first paper about product-service system indexed in the Web of Science occurred in 2002. Then,

in the next nine years, few papers were published and there were no register of papers published in 2005 and 2008. From 2011 to 2013, the number of papers increased drastically, indicating a fast growing interest in product-service system. Papers published from 2011 to 2013 represents 78,8% of the total.

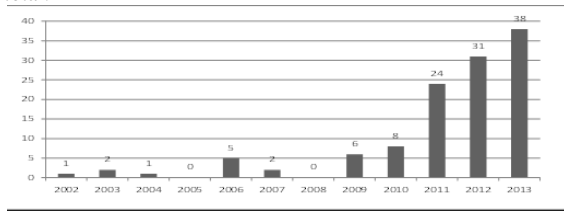


Fig. 1. Number of PSS papers per year from 2002 to 2013.

3.2. Number of papers per author and the co-authorship network

The bibliometric software collected a total of 386 authors from the sample. From them, authors who participated at least in three papers were selected, resulting in 24 authors. Table 1 presents the number of papers published by these 24 authors..

Table 1. Number of PSS papers per author.

Rank	Authors	Papers	Rank	Authors	Papers
1	Baines, TS	8	13	Shimomura, Y	4
2	Lightfoot, HW	8	14	Zhang, Z	4
3	Chu, XN	5	15	Evans, S	3
4	Durugbo, C	5	16	Johnson, M	3
5	Geum, Y	5	17	Lee, HS	3
6	Park, Y	5	18	Lee, S	3
7	Geng, XL	4	19	Mont, OK	3
8	Huang, GQ	4	20	Roy, R	3
9	Jiang, PY	4	21	Sakao, T	3
10	Kuo, TC	4	22	Smart, P	3
11	Qu, T	4	23	Tiwari, A	3
12	Shehab, E	4	24	Zhang, Y	3

It can be seen that there is a balanced participation of authors in the PSS field as well as there is a slight predominance of two authors: Baines and Lightfoot

It is also relevant to develop a co-authorship network to clarify the existence of collaborative work involved in the results of the number of papers per author. This network can describe whether an author has published alone or in group. Fig. 2 presents the co-authorship network in two parts; the first part considers authors of papers published from 2002 to 2010 and the second part includes authors of papers published from 2002 to 2013 (the full period). This separation was adopted since these periods seem to represent distinct moments of the evolution of the PSS field, as explained in the last section.

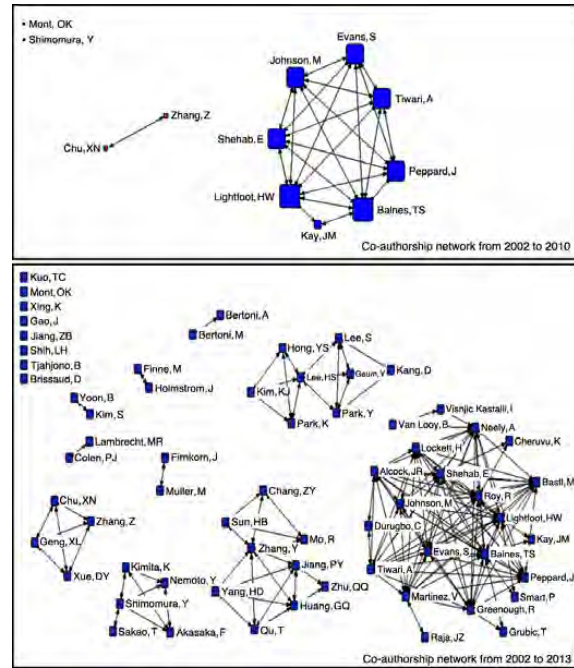


Fig. 2. Co-authorship networks from 2002 to 2010 and from 2002 to 2013.

The first network shown in Fig. 2 addressed authors who had participated in at least two PSS papers from 2002 to 2010. It suggests the presence of only two groups of authors. The largest one is comprised of eight authors and it has no central node, which means a direct relationship among their participants. Moreover, its members are mainly from Europe. The smallest group embraces two members, Zhang from China and Chu from Canada.

The second network of Fig. 2 includes papers from 2002 to 2013. Since there was a huge increase of publications in this period, new groups of authors were established. Four main groups can be noticed in this network. The largest one is comprised of 22 members and represents an extension of the main group noticed from 2002 to 2010. Baines and Lightfoot are the highest ranked author in this field with 8 articles each (Table 1). The authors from this group explore different research topics such as: servitization, business models, and uncertainties in implementing PSS. It can be considered a European group related to servitization discipline, but with some minor involvement of other countries such as USA. In addition, it presents important central nodes (Baines, Lightfoot, Evans, Shehab, Johnson, Tiwari, Peppard, Roy, Evans and Neely), which denotes authors who are responsible for the extension of the group collaboration. The second largest group includes 9 members; most of them from Chinese institutions. It should be pointed out in this group the fact that Zhang is a critical link between two small groups. The articles from this group has been achieved recently (after 2010) and they are concerned with technical aspects mostly (production planning, RFID and industrial PSS). The next two groups are constituted of 8 and 5 members, who represent respectively institutions from South Korea and Japan. The South Korean group also has a critical node, Lee, who connects two small

groups. This group is more diversified considering the explored research topics (sustainability and PSS technology tools). The Japan group has two important authors (Sakao and Shimomura) that are related to service engineering discipline. The information extracted from these co-authorship networks suggest that there is a relationship between groups and geographical regions, with minor or none relationships among them, which could be undesirable for the progress of the PSS research field. In spite of this fact, it can be reported a substantial evolution in the European collaboration, strengthened by the foundation of central nodes able to underpin further expansion of the group.

3.3. Number of papers per institution and the institutional network

This section describes the institutions and countries which have mostly contributed to the development of the PSS research field. In fact, this analysis adds to the previous one by clarifying in which institutions the PSS groups are placed. Based on the sample, the bibliometric software identified 123 institutions. A threshold of three papers per institution was adopted to enhance data analysis and presentation. Table 2 shows the results.

Table 2. Number of PSS papers per institution

Ranking	Institution	Papers
1	Cranfield University, United Kingdom	20
2	Shanghai Jiao Tong University, China	9
3	Seoul National University, South Korea	7
4	Tokyo Metropolitan University, Japan	5
5	Xi'an Jiaotong University, China	5
6	Aston University, United Kingdom	4
7	Katholieke Universiteit Leuven, Belgium	4
8	Linköping University, Sweden	4
9	Lulea University of Technology, Sweden	4
10	Lund University, Sweden	4
11	The University of Hong Kong, China	4
12	Aalto University, Finland	3
13	Chung Yuan Christian University, Taiwan	3
14	University of Bristol, United Kingdom	3
15	University of Cambridge, United Kingdom	3
16	University of Vaasa, Finland	3

As already expected after the results of the co-authorship networks, there is a predominance of European institutions, whose participation corresponds to 43,9% of the published papers. United Kingdom have an outstanding position in this ranking, with four institutions involved in PSS researches: Cranfield University, Aston University, University of Bristol and University of Cambridge; followed by Sweden with three institutions: Linköping University, Lulea University of Technology and Lund University; Finland with two institutions: Aalto University and University of Vaasa; and Belgium with the University of Leuven. The second largest contribution (27,8%) has been made by Asian countries, in particular by China, Taiwan, South Korea and Japan.

The collaboration among institutions can also be mapped through an institutional network. It improves the

understanding of the research groups when compared to the co-authorship network. In fact, a substantial part of the co-authorship network presented in Fig. 2 involves authors from the same institution. The institutional network is presented in Fig. 3 and it was developed using a threshold of two papers.

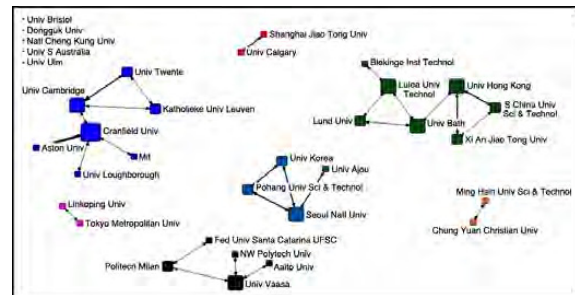


Fig. 3. Institutional network.

The information depicted in Fig. 3 suggests the main institutional collaboration regarding the PSS research field is concentrated in four main groups. The first group, which embraces 7 institutions, indicates Cranfield University and the University of Cambridge as key research centres and includes other members from United Kingdom, Belgium, United States and The Netherlands. The second group in which the most important nodes are the University of Bath, the University of Hong Kong and Lulea University of Technology, includes also 7 institutions and it has members from United Kingdom, China and Sweden. The third group is formed by 5 members and it is led by the University of Vaasa. It embraces institutions from Finland, United Kingdom, Italy, United States and Brazil. The fourth group is comprised of 4 South Korean institutions members and Seoul National University is its core node.

The institutional network shows some continental collaboration, in contrast to the co-authorship network. This fact can mean that the authors that passed the threshold of three papers, adopted for the co-authorship network, have little connections with foreign institutions. In addition, authors with minor participation in the PSS field tend to have higher foreign connections and can become a bridge for international collaboration in their institutions.

3.4. Number of papers per journal

The 118 papers considered in the sample were published in 45 journals. Among them, 13 journals include at least three papers related to PSS, which are presented in Table 3.

Table 3 highlights the substantial contribution of the Journal of Cleaner Production, which is dedicated to sustainable issues related to industrial development, and the contribution of journals from the operations and manufacturing areas, such as the International Journal of Production Research, the International Journal of Advanced Manufacturing Technology and the Journal of Engineering Manufacture. It should be also noticed the presence of journals from the information sciences area, such as Computers in Industry and Expert Systems with Applications, from the

services and business area, such as Service Business and Industrial Marketing Management and, at the end, journals from the design area, such as the Journal of Engineering Design and the Journal of Engineering and Technology Management.

Table 1. Number of PSS papers per journal

Ranking	Journals	Papers
1	Journal of Cleaner Production	19
2	Int. Journal of Production Research	11
3	Int. Journal of Adv. Manufacturing Technologies	9
4	Journal of Engineering Manufacture	8
5	Computers in Industry	7
6	Service Business	5
7	CIRP Ann-Manufacturing Technology	4
8	Expert Systems with Applications	4
9	Int. Journal of Operations Production Management	4
10	Industrial Marketing Management	3
11	Int. Journal of Computed Integrated Manufacturing	3
12	Journal of Engineering Design	3
13	Journal of Engineering Technology Management	3

3.5. The most used keywords and the keywords network

This analysis aims at mapping keywords used by PSS authors to define subjects addressed in their papers. Table 4 describes them based on a threshold of 5 papers. As a result, product-service system and servitization were the most used keywords. Furthermore, important subjects to the PSS field are confirmed through the keywords presented in Table 4.

Table 4. Number of PSS Keywords.

Ranking	Keywords	Papers
1	Product-Service System	83
2	Servitization	23
3	Sustainability	11
4	Design	10
5	Services	8
6	Manufacturing	6
7	Business model	5
8	Case study	5
9	Knowledge management	5
10	Service innovation	5

In addition, the keywords network also supports the explanation of the most important subjects addressed in the PSS field. This network, depicted in Fig. 4, is able of describing related and leading subjects. The development of this network considered the threshold of three papers.

The information in Fig. 4 shows the strongest relationships starting from the product-service system node. These, which are indicated by the thicker lines, are dealing with design, sustainability, case study, services and servitization.

Moreover, the borders subjects seem to indicate PSS research lines, such as: remanufacturing, service engineering,

customer relationship management, car sharing service, decision making and knowledge management. Other important facts seen in Fig. 4 are the presence of management issues of product-service system, such as: business models, technology management and supply chain management. Finally, there is a node reporting the case study method as the most adopted for the PSS field.

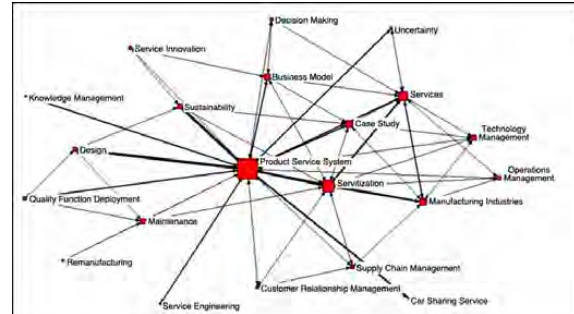


Fig. 4. Keyword network.

3.6. number of papers per journal

The 118 papers of the sample were cited 768 times in the Web of Science database. The eleven most cited ones were selected and are presented in Table 5, which also describes the number of citations received by them. Table 5 describes a great concentration in only three papers, which should be considered fundamental for the PSS field.

Table 5. - The twenty most cited PSS papers in Web of Science database.

Ranking	Papers	Citations
1	Mont (2002)	180
2	Baines et al. (2007)	161
3	Manzini and Vezzoli (2003)	73
4	Cook et al. (2006)	41
5	Baines et al. (2009)	38
6	Mont (2004)	34
7	Mont et al. (2006)	32
8	Sakao et al. (2009)	26
9	Maussang et al. (2009)	24
10	Schmenner (2009)	21
11	Evans et al. (2007)	21

3.7. The most cited references and the co-citation network

References are publications cited in papers; therefore the most cited ones represent publications which have mostly influenced the development of the research field. References with a minimum of 19 citations obtained from the 118 PSS papers considered in this study are presented in Table 6. These correspond to 33 references of 4277. From these, only six were in the sample (Baines et al., 2007; Mont, 2002; Manzini and Vezzoli, 2003), which indicates a limitation of Web of Science database or of the search string adopted in this study.

The co-citation network indicates the references which are commonly cited in a single paper. Fig. 5 shows the co-citation network developed for the references cited at least 10 times. It describes a balanced distribution among references, since it cannot be seen clearly groups. Additionally, the central nodes represent the most cited references in the papers. In fact, they are aligned to the results shown in Table 6.

Table 6. - The ten most cited PSS papers in Web of Science database.

Ranking	Reference	Cited Times
1	Baines et al. (2007)	50
2	Mont (2002)	49
3	Tukker (2004)	34
4	Goedkoop et al. (1999)	33
5	Manzini and Vezzoli (2003)	33
6	Aurich et al. (2006)	29
7	Vandermerwe and Rada (1988)	29
8	Oliva and Kallenberg (2003)	26
9	Wise and Baumgartner (1999)	24
10	Tukker (2006)	19

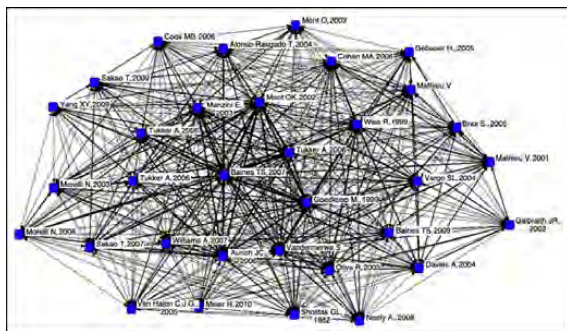


Fig. 5. The co-citation network.

4. Conclusion

This paper presented a bibliometric analysis of the product-service system research field based on a sample of 118 papers collected in the Web of Science database and published from 2002 to 2013. The development of quantitative metrics for the PSS field can supplement the existent literature reviews, which had mainly covered qualitative analysis. To this end, Vantage Point, UCINET and NetDraw software was used to implement the bibliometric and network analyses, which consisted of: number of papers per year, number of papers per author, co-authorship network, number of papers per institution, institutional network, number of papers per journal, the most used keywords, keywords network, the most cited papers, the most cited references and co-citation network.

The results described the main quantitative characteristics of the research field. In particular, it can be mentioned the fast growing of PSS papers from 2011 to 2013, confirming the relevance of the field. In addition, co-authorship and institutional networks showed the authors who had published more papers related to PSS and the research groups which

have been established over the last years, which are mainly located in Europe and Asia. Among the analyzed journals, the Journal of Cleaner Production stands out with 19 papers published, followed by journals from the operations and manufacturing areas, such as the International Journal of Production Research. At the end, the most cited papers and references were presented, indicating the knowledge foundation of the PSS field.

The limitations of this study are concentrated in the sample used to perform the analyses, which focused on data extracted from a single academic database. Furthermore, the development of literature reviews based solely on quantitative metrics, such the one presented in this paper, can lack relevant information to describe the research field.

In conclusion, this paper presents the results of an in-progress research project with aims at explaining the state-of-the-art of product-service system. Further research is required to achieve its goal, which involves the investigation of bibliometrics based on other academic databases, subjects addressed by the most important research groups, knowledge provided by the most cited papers and references and identification of research trends based on the keywords and citations.

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