

Review

# Systematic Literature Review—Effects of PSS on Sustainability Based on Use Case Assessments

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**Abstract:** Product-service systems (PSS) are often presented as an inherently sustainable business model. The argumentation is often based on theoretical considerations, which cite circular economy (CE) characteristics in PSS business models as an explanation. In this paper we examined to what extent positive and negative sustainability effects of PSS could actually be observed, based on use cases. For this purpose, we conducted a systematic literature review and analyzed the statements on sustainability effects based on the triple bottom line approach. We find that positive sustainability effects, especially on the environmental sustainability of PSS, are described disproportionately often, which may be indicating a possible publication bias. In addition, the methods used to derive statements on sustainability effects are very heterogeneous and often unsystematic, making it difficult to compare the described effects. Furthermore, we were able to identify drivers that are particularly often considered in literature to be responsible for sustainability effects. As a result, we were able to derive direct implications for future research in the field of sustainability assessment of PSS.

**Keywords:** product-service system; sustainability; systematic literature review; life-cycle assessment; environmental impact

## 1. Introduction

Product-service systems (PSS) are business models in which the product manufacturer usually offers services in addition to selling the products, or even takes over the operation of the products instead of selling them [1–3]. Due to digitalization, PSS business models are experiencing a revival, as can be seen in the mobility sector with numerous vehicle sharing or ride pooling providers [4,5]. This is accompanied by a variety of challenges in the transformation of the traditional business model [6–9], but there are also opportunities, especially in the area of sustainability [10,11]. Some studies consider PSS business models as inherently sustainable, while other authors point out specific conditions that must be met for PSS to be truly sustainable [12]. For example, some publications argue that PSS suppliers can implement holistic recycling and extended product life through the control of their products, e.g., by IoT (Internet of Things) solutions, thus improving sustainability in resource consumption [13]. Others point to changed customer behavior, whereby careless handling of products leads to increased wear and tear [14,15]. Due to the large number of heterogeneous findings on the effects of PSS on sustainability, this research intends to contribute to systematizing these statements. It will allow to draw conclusions about the actual sustainability effects of PSS on the basis of aggregated findings. Therefore, the authors focus on papers that analyze use cases and hence are able to make

evidence-based statements on sustainability effects. Since sustainability assessment generally faces different challenges from a methodological, data availability, and standardization perspective, it is important to consider the applied method of sustainability assessment [16–18]. The differences in the methods can have an impact on the outcome and rigor of the findings. Therefore, the sustainability assessment methods are characterized in order to identify challenges. In addition, we aim to derive potentials and needs for future research based on the findings from the literature review. The research objectives (RO) of this paper can be summarized into three statements, which are the following:

- RO1: The identification and analysis of sustainability effects with respect to their interrelationships in PSS.
- RO2: The characterization of the sustainability assessment of PSS with respect to methodological challenges and a description of the use cases as a research object.
- RQ3: The derivation of needs and recommendations for future research from the findings.

To achieve these objectives, 150 papers dealing with the sustainability assessment of PSS use cases were screened and 62 were considered in our research process as eligible to be examined in detail. We build on similar research as that of Guzzo et al. (2019) [19], who developed a circular innovation framework based on a use case-based literature review, by incorporating the findings of their study. Furthermore, the knowledge base is broadened through a different perspective on sustainability effects of PSS by subdividing the statements regarding sustainability effects into drivers and indicators. This makes cause-and-effect relationships visible in the debate. In addition, we address a possible publication bias, which is suspected due to the fact that positive sustainability effects are cited about 10 times more frequently than negative effects. Furthermore, we see a need for the development and application of a standardized methodology for the assessment of sustainability effects, as well as a general need for further empirical studies on the sustainability effects of PSS.

## 2. Methods

To achieve the research objectives described above, a literature review was conducted, and the results were analyzed with respect to the RO. The search and analysis process is explained in the following sections.

### 2.1. Systematic Literature Review for Generation of the Literature Body

In order to meet the goal of the research in providing an overview of the status of the sustainability effects of PSS reported in the scientific debate, a systematic literature review was chosen as the method. We followed the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) process [20], whereby the selection process is shown in Figure 1 and explained below.

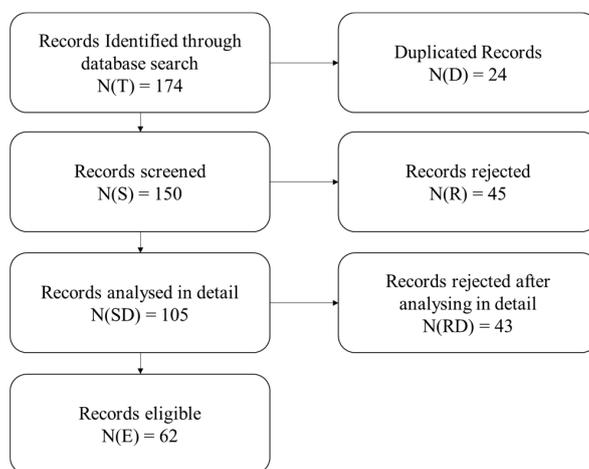


Figure 1. Selection process.

For the search we have created a term matrix in English (Table 1), as well as in German, and created search strings by combining the terms within each block with OR.

**Table 1.** Term matrix for the generation of the literature body.

Term matrix	Block 1	Block 2	Block 3
Synonyms	Product-Service System	Sustainability	Application, Use Case, Survey
Related terms/ Sub-aspects	Industrial product service system	Environment, Ecological, Social, Emissions	Real-world application, practical example, case study, industry application, exemplification, prototype

The search strings for each Block were searched in the categories “abstract,” “title,” and “indexing terms” for the last 15 years, and the results for each block were combined with AND. The search was conducted in the following databases:

- SCOPUS
- Business Source Complete
- IEEE Xplore

In a first step, this resulted in 174 publications, of which 24 were duplications and, after an initial screening, a further 45 publications were removed. These entries were removed because they either did not describe a use case or had no real relation to sustainability. Despite the use of German search terms, all publications found were in English. In a second, more detailed screening step, 43 publications were again removed if there was a reference to sustainability but no assessment of sustainability effects or if the description of the PSS use case did not show which product and service were involved. This resulted in a sample size of 62 entries for the final literature body.

## 2.2. Analysis Process

The aim of the content analysis was to identify and analyze the sustainability effects based on PSS use cases from the literature. For this purpose, in a first step the statements regarding the effects of PSS on sustainability (indicators) were examined and, in a second step, the causes for these effects (drivers) were analyzed. The indicators are based on the triple bottom line approach [21] and are broken down according to the three dimensions of sustainability (ecological, economic, and social sustainability) as follows, according to Rodriguez et al. (2002) [22]:

### Ecological Sustainability

- Natural Resource Use
- Environmental Management
- Pollution Prevention

### Economic Sustainability

- Profit
- Cost Savings
- Economic Growth
- Research and Development

### Social Sustainability

- Standard of Living
- Education
- Community

- Equal Opportunity

We have categorized the drivers on the basis of the statements found for the indicators in the literature body. Based on Mayring [23], a qualitative content analysis was conducted. The definitions for the drivers were inductively generated from the statements by applying summarization as an interpretation technique [24]. When creating the categories, we defined rules that allowed the researchers to perform tagging in a consistent way. We deliberately did not commit to a uniform level of abstraction for all categories. This is because the level of detail in the use case description in the papers was highly heterogeneous. We have determined the following categories of drivers for the sustainability indicators:

- Optimized Operations and Maintenance describes various mechanisms and approaches to use products and services more efficiently in their application context, for example, to reduce failure rates or streamline processes. Rule: Papers referring to services enhancing operations and maintenance in general.
- Closed Loop Business Models covers all aspects of the capabilities of PSS business models to control products to their end-of-life. Rule: Papers referring to services enhancing operations and maintenance in general.
- Health Monitoring and IoT-based Solutions groups together digitization technologies that function as sustainability drivers. Rule: Papers presenting IoT solutions for condition monitoring as a driver for sustainability.
- Prolonged Product Lifetime and Design of Durable Products refers to the fact that with PSS business models it is economically advantageous for operators to extend the product lifetime in order to reduce costs for replacement and MRO (maintenance repair and overhaul). Rule: Papers that address longer product life or durability as general drivers of the PSS business model.
- Substitution of Resource Intensive Systems describes the fact that PSS enable in some cases solutions that are inherently more resource-efficient (e.g., operating water purifier instead of selling bottled water). Rule: Papers that present inherently more sustainable solution principles provided by PSS substituting sales-oriented offerings.
- Sharing Business Model and Optimized Resource Allocation subsumes the characteristics of sharing solutions, whereby potentials of unused resources are utilized in different ways. Rule: Papers that describe the intensified use of otherwise idle resources in new application contexts.
- Sales of Services refers to changes that are triggered by the offering and sale of services alone. Rule: Papers highlighting higher volumes of sales due to introduction of PSS as a driver (mostly for economic indicators).
- Unexpected Customer Behavior in Usage Phase addresses the change in customer behavior when they use PSS solutions instead of purchased products (e.g., customers using rented cars less carefully). Rule: Papers referring to changes in customer behavior that drive sustainability outcomes.
- Riskiness of Business Model refers to the novel risk structures in PSS business models compared to traditional business models. Rule: Papers referring to the changed risk structures of PSS compared to traditional business models.
- Rebound and Backfire Effect addresses the phenomena according to which positive sustainability effects achieved through improvements are offset or even turned into the negative (e.g., by parallel changes in the negative behavior of people and systems). Rule: Papers referring explicitly to various aspects of the rebound and backfire effects as a driver.

The tagging within the papers was carried out independently by the authors on the basis of the defined indicators and drivers. In addition, the direction of the observed sustainability effect (positive/negative) was recorded.

### 3. Results

In this section, the literature body is first described and then the analysis of its content is presented.

#### 3.1. Description of the Literature Body

In the following paragraphs, the literature body will be characterized regarding a description of the scientific sources, types of contributions, and types of use cases covered in order to be able to better classify the results.

##### 3.1.1. Distribution of Publications Over Time and According to Journals

The chronological distribution of the 62 publications is shown in Figure 2. In this sample, the earliest publication was in 2007. From 2011 to 2016, a constant low single-digit publication volume is observed in our sample. In 2017 there was a very strong increase compared to the previous years. In the following years of 2018 and 2019 the number decreased again, but is still high compared to the years before. At the time of the literature body survey, there was no publication in 2020, which has to do with the fact that we conducted the database search at the beginning of the year. Overall, we can observe a renewed increase in interest and relevance of PSS in the scientific community, which is consistent with the overall increase in the number of publications in the sample from 2007.

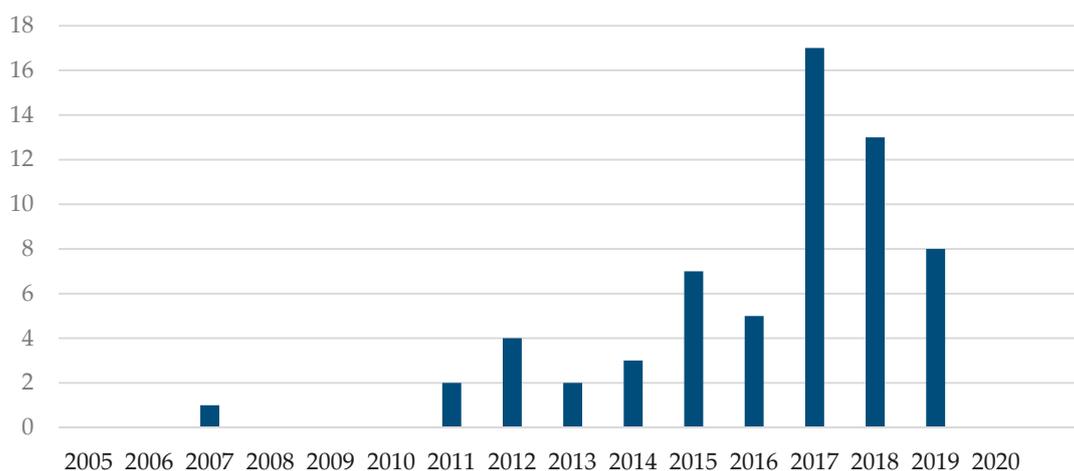


Figure 2. Distribution of publications over time.

The distribution of publications per journal is shown in Figure 3. By far the most publications that met the requirements (sustainability effects in PSS use cases) were published in the *Journal of Cleaner Production*. Among other subjects, this journal addresses sustainability topics with practical relevance, which provides an explanation for the high number of papers. *Product-Service Systems across Life Cycle, Sustainability*, and *International Journal of Production Research*, all of which also have a focus on sustainability and/or PSS, and are ranked with a similar frequency. It is noticeable that in total almost 41% of the papers come from very heterogeneous sources, i.e., from publications with only one publication. This can be explained by the fact that many of the papers come from the IEEE Xplore database. Thus, very different use cases were considered with regard to the application context, the industry, the research focus, etc., and hence these papers were published in the corresponding specialized publications. This explains the heterogeneity of the sources of papers that are taken from the IEEE Xplore database.

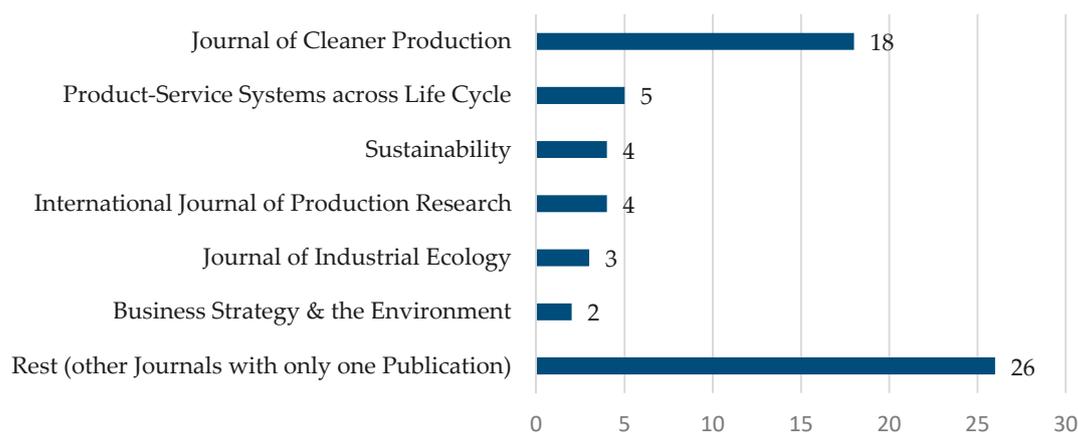


Figure 3. Number of publications per journal.

The papers considered can be divided into three categories according to their type of scientific contribution (Figure 4). We distinguish papers into case studies, in which a phenomenon was explicitly investigated by means of use cases, into application use cases, in which the use case served for validation, illustration, or illustration purposes, and finally into literature reviews, in which findings were based on secondary data. Just over half of the papers are case studies that have actually carried out dedicated sustainability assessments of PSS use cases, with different focuses. A large proportion of the papers belong to the category application use case, in which the sustainability assessment was carried out in the context of a validation, illustration, or illustration of a method or technology. A very small proportion are literature reviews, which also report on real existing PSS, but have not collected primary data. Overall, it can be stated that, due to the heterogeneous focus of the papers, the research objectives vary, which limits the comparability of the statements. For example, application use cases usually focus on specific application areas and therefore often only consider this narrow scope in the sustainability assessment. In contrast, case studies tend to look at the subject matter more extensively in order to achieve their respective research objectives. The high percentage of application use cases can be explained by the fact that many papers are taken from the IEEE Xplore database. Publications in this database tend to have a strong focus on papers that investigate application-oriented solutions in an engineering context.

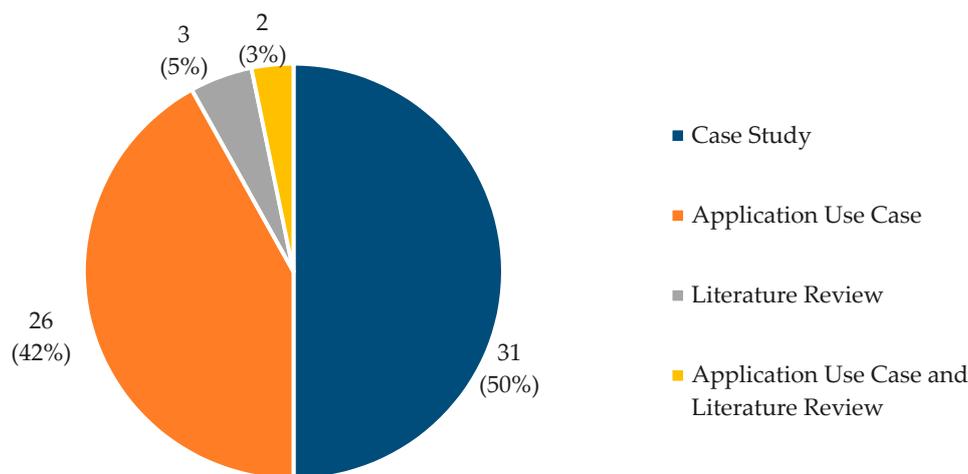
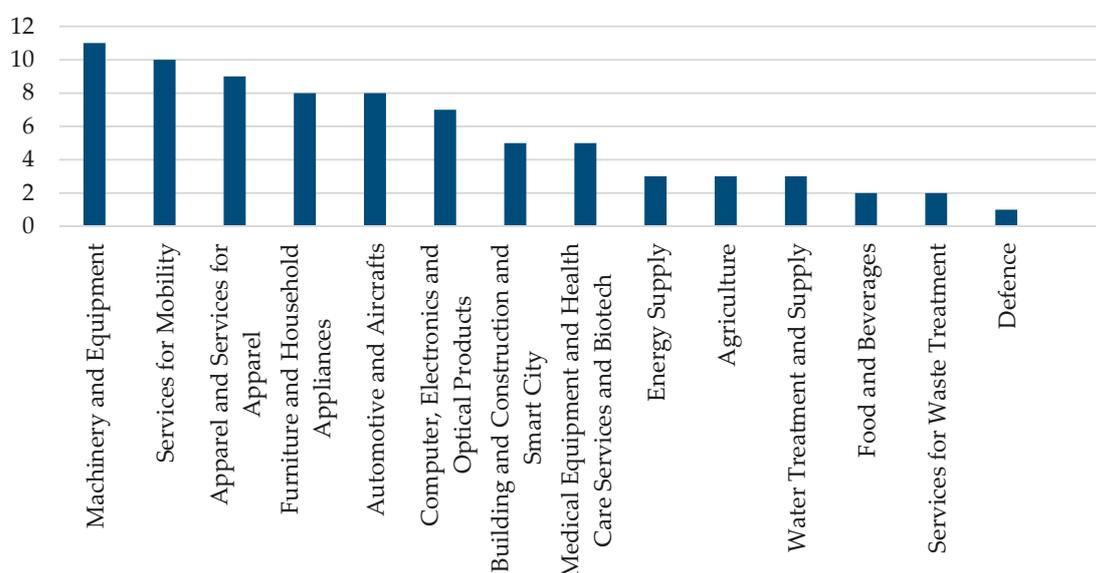


Figure 4. Number of papers according to the type of use case analysis.

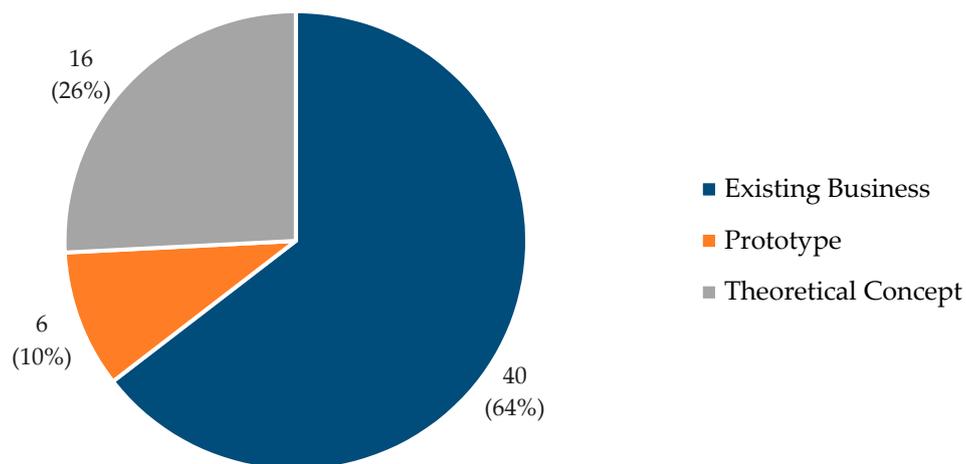
### 3.1.2. Description of Use Cases presented in Publications

Figure 5 lists the number of papers that address at least one use case in an industry. This means that papers can either examine several use cases of the same industry, whereby the paper is only counted once, or one paper can examine several use cases of different industries, whereby the paper is counted several times in the respective industries. Most of the papers were analyzed in the machinery and equipment sector, which can be explained by the fact that this area is attractive for PSS business models, because the operation of complex assets as a service especially and the sale of additional services in general promises to be a differentiating factor and generate additional profits. In second place is the area of services for mobility, which is a classic application area for PSS. Here, various sharing models (e.g., car, scooter, bike, and ride sharing) are mentioned in particular, which are a frequent research object in the PSS area and sustainability research. Surprisingly often use cases in the area of apparel and services for apparel have been investigated in the literature. This may be due to the already existing sharing business models, e.g., for wedding dresses, and the recycling of secondhand clothes which is accepted in this sector. Overall, several use cases within a sector or across sectors were examined in individual papers.



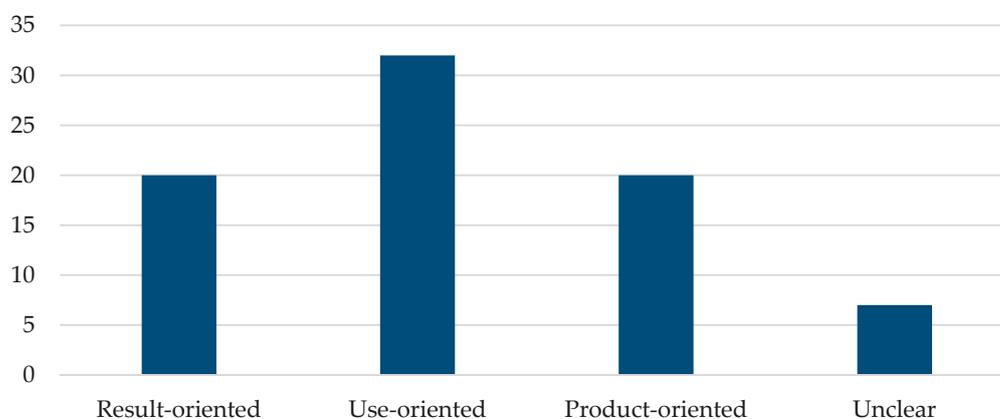
**Figure 5.** Number of papers describing at least one use case in the respective industry.

For a breakdown of the use cases according to their maturity in the business model, we have divided them into the categories: Existing business, prototype, and theoretical concept (Figure 6), whereby the latter refers to theoretical concepts that are based on existing business models but have not yet been implemented. The predominant share of use cases refer to existing businesses, which correspond to the paper's research focus. The relatively large share of theoretical concepts can be explained by the fact that the data collected for these concepts is usually based on existing business models. For this reason, this type of paper was retained in the literature body. The same applies to the category prototypes. Overall, it is noticeable that, with 36%, a large proportion of papers do not consider existing business models at all, which may also be explained by the fact that PSS business models have not yet become widely adopted.



**Figure 6.** Number of papers according to the levels of product-service systems (PSS) maturity described in the use cases.

In addition, we have divided the use cases into the common categories of PSS, which are result-, use-, and product-oriented PSS according to Tukker [10]. In some cases, the publications did not clearly describe which PSS type was involved. In these cases, the category “unclear” was chosen. The distribution is shown in Figure 7. The largest share is made up of use-oriented PSS, whereby result- and product-oriented PSS are present in roughly equal proportions and both have a share of about 37% less than use-oriented PSS in the sample. It should be examined how the distribution develops over a longer period of time if the trend towards use-oriented and result-oriented PSS continues.



**Figure 7.** Number of papers according to the type of PSS described in the use cases.

### 3.2. Debate on Sustainability Effects of Product-Service Systems (PSS) in Literature

In this section we discuss the results of our literature review. The following sections present results on a possible publication bias, methodological challenges of the sustainability assessment of PSS, and analysis of sustainability effects of PSS. An overview of the literature body is presented in Table 2.

Table 2. Literature body of eligible papers.

No.	Reference	Main Contribution	# Use Cases	Use Case Description	Sustainability Assessment Approach
1	Amasawa, Eri, et al. (2018). Designing interventions for behavioral shifts toward product sharing: The case of laundry activities in Japan. <i>Sustainability</i> , 10 (8). [25]	Study of consumer behavior regarding sharing products in order to propose approaches to induce behavioral shifts towards product sharing	1	Implementation of a communal laundromat in an apartment building as a shared resource	Interviews and life cycle assessment (LCA)
2	Bressanelli et al. (2018). Exploring how usage-focused business models enable circular economy through digital technologies. <i>Sustainability</i> , 10 (3). [26]	Analysis of how digital technologies enable CE, servitized business models (BM), and proposition of a conceptual framework for implementing such BMs	1	Household appliance retailer adopting a servitized business model	Interviews
3	Teles et al. (2018). Sustainability measurement of product-service systems: Brazilian case studies about electric car-sharing. <i>International Journal of Sustainable Development and World Ecology</i> , 25 (8). [27]	Sustainability analysis given projects	2	Electric carsharing projects	Interviews, questionnaire, and documents
4	Chun, Lee (2017). Environmental impacts of the rental business model compared to the conventional business model: a Korean case of water purifier for home use. <i>International Journal of Life Cycle Assessment</i> , 22 (7). [28]	Comparative analysis of environmental impacts of rental and sales business model	1	Home-use water purifier as rental business model	LCA and sensitivity analysis
5	Priyono (2017). Understanding the benefits of product-service systems for parties involved in remanufacturing. <i>Journal of Industrial Engineering and Management</i> , 10 (2), 323–351. [29]	Investigation on how PSS provides economic and environmental benefits to OEMs (original equipment manufacturers), remanufacturers and customers	2	Two companies producing photocopy machines and jet engines respectively	Interviews and observations
6	Brun-Petersen et al. (2017). Cultivating User-ship? Developing a Circular System for the Acquisition and Use of Baby Clothing, <i>The Journal of Design, Creative Process &amp; the Fashion Industry</i> , 9 (2), 214–234. [30]	Study of the environmental significance of subscription-based PSS rather than sales	1	Subscription service for baby clothing, which offered a range of eco-certified garments for rent	Interviews and observations
7	Gilles et al. (2016). The Sustainable value proposition of PSSs: the case of ECOBEL “Shower head”, <i>Procedia CIRP</i> , 47, 12–17. [31]	Analysis of the sustainable value proposition of a given case company	1	Shower heads and additional services for hospitals and health care facilities	Interviews, media, and documents
8	Sousa et al. (2015). Product-service systems as a promising approach to sustainability: exploring the sustainable aspects of a PSS in Brazil, <i>Journal of Cleaner Production</i> , 87, 452–462. [32]	Investigation of sustainable effects of PSS compared to sales of the traditional product	1	Water purifying system offered to shops and restaurants as an alternative to bottled water	Interviews and observations
9	Tseng et al. (2019). A causal sustainable product-service system using hierarchical structure with linguistic preferences in the Ecuadorian construction industry, <i>Journal of Cleaner Production</i> , 230, 477–487. [33]	Assessment of sustainable PSS	1	Ecuadorian construction industry	Decision-making trial and evaluation laboratory (DEMATEL) and analytical network process (ANP)
10	Stal et al. (2017). Sustainable Consumption and Value Propositions: Exploring Product-Service System Practices Among Swedish Fashion Firms, <i>Sustainable Development</i> , 25 (6), 546–558. [34]	Analysis of sustainable value proposition of PSS	9	Consumption of sustainable fashion articles in Sweden	Interviews, observations, reports, and online material
11	Evans et al. (2007). Industrialization as a key element of sustainable product-service solutions, <i>International Journal of Production Research</i> , 45 (18–19), 4225–4246. [35]	Description and sustainability assessment of three cases in which new PSS have been introduced	3	Various types of catering and food delivery services	Action research and LCA
12	Retamal et al. (2017). Product-service systems in Southeast Asia: Business practices and factors influencing environmental sustainability, <i>Journal of Cleaner Production</i> , 143, 894–903. [36]	Investigation of factors enabling or inhibiting sustainability of PSS business models through case studies	20	Various sharing providers in mobility, household appliance, fashion industry	Interviews
13	Sousa-Zomer et al. (2018). Cleaner production as an antecedent for circular economy paradigm shift at the micro-level: Evidence from a home appliance manufacturer, <i>Journal of Cleaner Production</i> , 185, 740–748. [37]	Case-based research approach for exploration of cleaner production principles in manufacturing companies to understand how this enables circular economy implementation	1	Water filter subscription in a closed-loop business model including services	Interviews and document analysis

Table 2. Cont.

No.	Reference	Main Contribution	# Use Cases	Use Case Description	Sustainability Assessment Approach
14	Överholm (2017). Alliance formation by intermediary ventures in the solar service industry: implications for product–service systems research, <i>Journal of Cleaner Production</i> , 140, 288–298. [38]	Study of types of PSS alliances and their formation process for value creation	7	Solar service firms for building, financing and maintaining solar panels	Interview, observations, and document analysis
15	De los Rios, Charnley (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design, <i>Journal of Cleaner Production</i> , 160, 109–122. [39]	Research on industry best practices for closed-loop material flows in sustainable PSS	8	Diverse product-as-a-service cases from automotive, electronics, furniture, and machinery industry	Interviews and document analysis
16	Corvelec, H, & Stal, I. H. (2017). Evidencing the waste effect of Product-Service Systems (PSSs), <i>Journal of Cleaner Production</i> , 145, 14–24. [40]	Waste-centric analysis of fashion PSS case to demonstrate that PSS do not automatically foster sustainability	8	PSS that promote rental, reuse, repair, and recycling of clothes	Interviews, observations, and document analysis
17	Finkorn, J. & Müller (2012). Selling Mobility instead of Cars: New Business Strategies of Automakers and the Impact on Private Vehicle Holding, <i>Business Strategy and the Environment</i> , 21 (4), 264–280. [41]	Empirical study on car-sharing case's impact on private vehicle possessions in the city of Ulm	1	Car-sharing	Empirical study
18	Shokohyar et al. (2014). A model for integrating services and product EOL management in sustainable product service system (S-PSS), <i>Journal of Intelligent Manufacturing</i> , 25, 427–440. [42]	Examination of ecologic and economic impact of warranty services	1	Service providers for notebooks in Iran	LCA
19	Firnorn, J. & Müller, M. (2011). What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm, <i>Ecological Economics</i> , 70 (8), 1519–1528. [43]	Analysis of the sustainability impact	1	Car-sharing	Simulation
20	Lindahl et al. (2014). Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases, <i>Journal of Cleaner Production</i> , 64, 288–296. [44]	Assessment of environmental friendliness of three PSS use cases in comparison to sales	3	Components for paper mills, cleaning of building exteriors, and compacting soil	Interviews and LCA
21	Lelah et al. (2011). Contributions to eco-design of machine-to-machine product service systems: the example of waste glass collection, <i>Journal of Cleaner Production</i> , 19 (9–10), 1033–1044. [45]	Identification of critical issues concerning eco-design of Machine2Machine PSS applications	1	Glass-waste collection service	LCA
22	Gelbmann et al. (2015). Integrative re-use systems as innovative business models for devising sustainable product–service-systems, <i>Journal of Cleaner Production</i> , 97, 50–60. [46]	Analysis of three ecologically oriented work integration social enterprises (ECO-WISE) PSS business models focusing on re-use	3	Networks for reuse of products, and social services	Observations and document analysis
23	Erkoyuncu et al. (2019). An effective uncertainty based framework for sustainable industrial product-service system transformation, <i>Journal of Cleaner Production</i> , 208, 160–177. [47]	Analysis of seven use case companies to develop a framework assisting in achieving more sustainable IPSS. Validation took place with two more use cases	7	Diverse providers of professional services in manufacturing, aerospace, enterprise industry	Interviews
24	Chang et al. (2019). A rough-fuzzy DEMATEL-ANP method for evaluating sustainable value requirement of product service system. <i>Journal of Cleaner Production</i> , 228, 485–508. [48]	Proposal of the product value state model (PVSM) method to elicit value requirements which help PSS deliver more sustainability	1	Smart excavator company	Survey and team of experts
25	Pieroni et al. (2019). Configuring New Business Models for Circular Economy through Product-Service Systems. <i>Sustainability</i> , 11 (13), 3727. [49]	Demonstration of a business model configurator for circular economy in two Nordic furniture companies	2	Two Nordic manufacturers in furniture industry	Workshops
26	Fargnoli et al. (2018). Product service-systems implementation: A customized framework to enhance sustainability and customer satisfaction, <i>Journal of Cleaner Production</i> , 188, 387–401. [50]	Proposition of a methodology to assess the potential environmental benefits from the implementation of PSS	1	Manufacturing company of biomedical devices	LCA, life cycle costing (LCC), market research, and questionnaires
27	Mourzis et al. (2018). A Lean PSS design and evaluation framework supported by KPI monitoring and context sensitivity tools, <i>The International Journal of Advanced Manufacturing Technology</i> , 94, 1623–1637. [51]	Application of a framework for lean PSS design	1	Company in the mold-making industry	Interviews

Table 2. Cont.

No.	Reference	Main Contribution	# Use Cases	Use Case Description	Sustainability Assessment Approach
28	Song et al. (2018). An environmentally conscious PSS recommendation method based on users' vague ratings: A rough multi-criteria approach, <i>Journal of Cleaner Production</i> , 172, 1592–1606. [52]	Introduction of a method for PSS customers to assess the environmental superiority of given PSS solutions	1	Elevator manufacturing company	Interviews
29	Yamada et al. (2018). A Strategy of Providing Upgradable Product Service System for Economic and Environmental Balance, <i>IOS Press BV</i> , 7, 1155–1164. [53]	Development of a decision-making method for upgrading PSS towards more sustainability	1	Home appliance and furniture packaged leasing	Product reports
30	Arabi et al. (2018). Optimizing a warranty-based sustainable product service system using game theory, <i>International Journal of Sustainable Engineering</i> , 11 (5), 330–341. [54]	Proposal of a mathematical model to optimize the warranty and replacement period to minimize total cost of usage	1	Local chain of notebook service shops from Iran	Service data from company
31	Sun et al. (2017). Configuring use-oriented aero-engine overhaul service with multi-objective optimization for environmental sustainability, <i>Journal of Cleaner Production</i> , 162, S94–S106. [55]	Development of an approach to configure maintenance services for PSS	2	Configuration of aero-engine overhaul services and part repair services	Engineering data from company and interviews
32	Song et al. (2017). A customization-oriented framework for design of sustainable product/service system, <i>Journal of Cleaner Production</i> , 140, 1672–1685. [56]	Introduction of a module-based design framework to support customization of sustainable PSS in early design phases with a validation in the elevator industry	1	Elevator manufacturing company	Interviews, observations and documents
33	Tsai et al. (2017). Design of Personalized Product Service System Utilizing Multi-Agent System, <i>Advanced Engineering Informatics</i> , 43, 845–851. [57]	Presentation of a multi-agent-based personalized PSS (MAPPSS) development model supporting quick adjustments for external changes and customer response	1	Male clothing industry	Data from test users of the IT implementation
34	Gobert et al. (2017). Intellectual and Territorial Capital for the Sustainability Assessment of a Servitization Project, <i>European Conference on Intellectual Capital</i> . [58]	Provision of a framework for territorial PSS assessment	1	Small household equipment manufacturer renting products to customers	Questionnaire and interviews
35	Peruzzini et al. (2016). Design for Sustainability in PSS: Evidences of QFD-Based Method Application, <i>IOS Press</i> , 4, 97–106. [59]	Application of a systematic QFD (quality function deployment)-based methodology to demonstrate its validity for the development of sustainable PSS solutions	1	Manufacturer of green-roofs allowing vegetation to grow on it	Focus group workshop
36	Barquet et al. (2016). Sustainable product service systems —from concept creation to the detailing of a business model for a bicycle sharing system in Berlin, <i>Procedia CIRP</i> , 40, 524–529. [60]	Development of a support for companies to create sustainable PSS business models with application to case in mobility sector	1	Bicycle sharing system	Scenario technique
37	Salazar et al. (2015). Eco-designing Product Service Systems by degrading functions while maintaining user satisfaction, <i>Journal of Cleaner Production</i> , 87, 452–462. [61]	Introduction of a method to make existing PSS more environmentally friendly while keeping customer satisfaction high	1	Manufacturer of environmental sensor applications	LCA
38	Chiu et al. (2015). A systematic methodology to develop business model of a product service system, <i>International Journal of Industrial Engineering</i> , 22 (3), 369–381. [62]	Proposal of a methodology to develop PSS business models to enhance market share and sustainability with illustration	1	Manufacturer of projectors, LCD monitors, digital cameras, LED lighting products	Interviews
39	Xing et al. (2013). A sustainability-oriented multi-dimensional value assessment model for product-service development, <i>International Journal of Production Research</i> , 51 (19), 5908–5933. [63]	Introduction of a sustainability assessment method for PSS	1	Solar heating system	Net present value (NPV) approach and LCA
40	Peruzzini et al. (2013). A Sustainability Lifecycle Assessment of Products and Services for the Extended Enterprise Evolution, <i>Product Lifecycle Management for Society</i> , 409, 100–109. [64]	Proposal of a method for sustainability assessment of PSS	1	Internet-connected washing machine	LCA, LCC, and social life cycle assessment (SCLA)

Table 2. Cont.

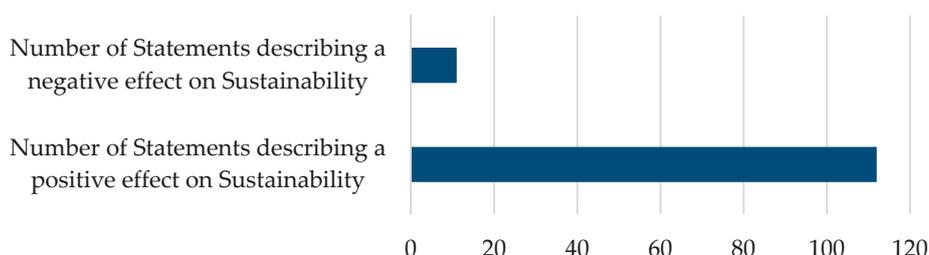
No.	Reference	Main Contribution	# Use Cases	Use Case Description	Sustainability Assessment Approach
41	Lee et al. (2012). Dynamic and multidimensional measurement of product-service system (PSS) sustainability: a triple bottom line (TBL)-based system dynamics approach, <i>Journal of Cleaner Production</i> , 32, 173–182. [65]	Introduction of a method for sustainability assessment of PSS	1	Public bike-sharing system operating globally	Simulation
42	Andreoni et al. (2012). Ergonomics and design for sustainability in healthcare: ambient assisted living and the social-environmental impact of patients lifestyle, <i>IOS Press</i> , 41, 3883–3997. [66]	Proposal of a development approach for ergonomic and sustainable design in healthcare	2	Sustainable product development performed by children and monitoring of elderly people through Internet of Things (IoT) solutions	LCA and focus group workshop
43	Kjaer et al. (2019). Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption, <i>Journal of Industrial Ecology</i> , 23 (1), 22–35. [67]	Proposal of a framework that aims to support analyses of PSS and their potential to lead to absolute resource decoupling	3	Laundry-service, subscription of children’s’ clothing, leasing of health care clothing	Secondary sources
44	Bridgens et al. (2019). Closing the Loop on E-waste: A Multidisciplinary Perspective, <i>Journal of Industrial Ecology</i> , 23 (1), 169–181. [68]	Analysis of a circular PSS material recovery	1	Mobile phone	LCA with data from experiments
45	Guzzo et al. (2019). Circular Innovation Framework: Verifying Conceptual to Practical Decisions in Sustainability-Oriented Product-Service System Cases, <i>Sustainability</i> , 11 (12), 1–19. [19]	Provision of a circular innovation framework based on literature-based case studies	45	Various cases from agriculture, construction, clothing, consumer goods, and other industries	Systematic literature review
46	Catulli et al. (2017). Product Service Systems Users and Harley Davidson Riders: The Importance of Consumer Identity in the Diffusion of Sustainable Consumption Solutions, <i>Journal of Industrial Ecology</i> , 21 (5), 1370–1379. [69]	Analysis of sociocultural aspects of PSS consumption in consumer markets by a comparative analysis regarding consumption with and without ownership	2	Motorbikes and car-sharing service	Systematic literature review
47	Vidickiene et al. (2019). Servitization as a tool to increase vitality of ageing rural community, <i>European Countryside</i> , 11 (1), 85–97. [70]	Development of an organizational model to implement PSS in agriculture industry	1	Renting land for agriculture businesses in Lithuania	Interviews
48	Reim et al. (2018). Mitigating adverse customer behaviour for product-service system provision: An agency theory perspective, <i>Industrial Marketing Management</i> , 74, 150–161. [14]	Development of a theoretical understanding and mitigation mechanisms of adverse customer behavior for PSS provision	2	Manufacturers of construction equipment and automotive parts including services	Interviews
49	Cook (2018). Product service system innovation in the smart city, <i>The International Journal of Entrepreneurship and Innovation</i> , 19 (1), 46–55. [71]	Exploration of context as a sociotechnical factor in PSS innovation by analyzing use case	1	Bike-sharing in Copenhagen	Observations and interviews
50	Kuo et al. (2012). The optimisation of maintenance service levels to support the product service system, <i>Journal of Production Research</i> , 50 (23), 6691–6708. [72]	Analysis of different types of integrated maintenance services through multi-attribute utility analysis to discuss overall utility of maintenance service	1	Manufacturing company of consumer electronics products	Questionnaire and mathematical model
51	Sumyle, D. & Ribašauskienė, E. (2017). Servitization of Lithuanian agricultural cooperatives, <i>Management Theory and Studies for Rural Business and Infrastructure Development</i> , 39 (4), 510–523. [73]	Exploration of the current level of servitization in agriculture industry	177	Agriculture cooperatives in Lithuanian	Interviews and statistical data analysis
52	Linder et al. (2017). Circular Business Model Innovation: Inherent Uncertainties, <i>Business Strategy and the Environment</i> , 26 (2), 182–196. [74]	Exploration of challenges for the implementation of circular business models	1	Bike manufacturing company	Interviews and survey
53	Pal (2016). Extended responsibility through servitization in PSS, <i>Journal of Fashion Marketing and Management</i> , 20 (4), 453–470. [75]	Study on how companies in fashion industry operating with used-clothing PSS extend their responsibilities	7	Repair, collection and reuse, leasing of baby clothes, lending of designer clothes, redesign service, information service for drop-off locations.	Interviews and document analysis

Table 2. Cont.

No.	Reference	Main Contribution	# Use Cases	Use Case Description	Sustainability Assessment Approach
54	Zhang et al. (2015). Sustainable bike-sharing systems: characteristics and commonalities across cases in urban China, <i>Journal of Cleaner Production</i> , 97, 124–133. [76]	Exploration of characteristics and commonalities between bike sharing systems in five cities in China	5	Bike-sharing systems	Secondary sources
55	Krueger et al. (2015). Integrative Service Innovation: An Industrial Use Case. <i>IEEE 17th Conference on Business Informatics</i> , 1, 217–223. [77]	Illustration of the integrative and innovative business model design method (iSIM) for PSS	2	Smart services for remote health assessment of machinery and maintenance optimization	Secondary sources
56	Lim et al. (2018). Design of informatics-based services in manufacturing industries: case studies using large vehicle-related databases, <i>Journal of Intelligent Manufacturing</i> , 29, 497–508. [78]	Description of the design process of informatics-based services	2	Digital services for health and operations management in automotive sector	Action research
57	Ding et al. (2017). Environmental and economic sustainability-aware resource service scheduling for industrial product service systems, <i>Journal of Intelligent Manufacturing</i> , 28, 1303–1316. [79]	Solving of a multi-objective resource service scheduling problem in industrial PSS through an algorithmic approach	1	Blower power equipment manufacturer	Customer and operational data
58	Mourtzis et al. (2017). Cloud-Based Augmented Reality Remote Maintenance Through Shop-Floor Monitoring: A Product-Service System Approach, <i>Journal of Manufacturing Science and Engineering</i> , 139 (6). [80]	Introduction of a cloud-based augmented reality (AR) maintenance service	1	Production plant of white-good manufacturer	Operational data
59	Wrasse et al. (2016). Development and Evaluation of Solar Energy B2B Solutions, <i>Procedia CIRP</i> , 47, 364–369. [81]	Application of a PSS V-model development approach in an early stage	1	Solar home systems	Action research
60	Song et al. (2015). An integrative framework for innovation management of product-service system, <i>International Journal of Production Research</i> , 53 (8), 1–17. [82]	Presentation of a framework of innovation management for PSS	1	Vending machine manufacturer including service network	Observations, workshops, and interviews
61	Rondini et al. (2018). A multi-criteria decision making approach for prioritising product-service systems implementation in smart cities, <i>International Journal of Management and Decision Making</i> , 17 (4), 415–446. [83]	Expansion of the engineering value assessment (EVA) method	7	Smart city concepts for the City of Bergamo	Literature and focus group workshop
62	Liu et al. (2014). Constructing a sustainable service business model: An S-D logic-based integrated product service system (IPSS), <i>International Journal of Physical Distribution &amp; Logistics Management</i> , 44 (1–2), 80–97. [84]	Conceptual construction of a service-dominant (S-D) logic-based integrated PSS business model	2	Renting products in aero and IT industry	Systematic literature review

### 3.2.1. Publication Bias

Overall, far more positive than negative effects of PSS on sustainability are mentioned in the literature body (Figure 8): Almost 10 times as many positive statements are made as negative ones. This reflects the fundamental opinion in the literature that PSS are beneficial to sustainability. It can be noted that, overall, only a few papers indicated or discussed negative sustainability effects.

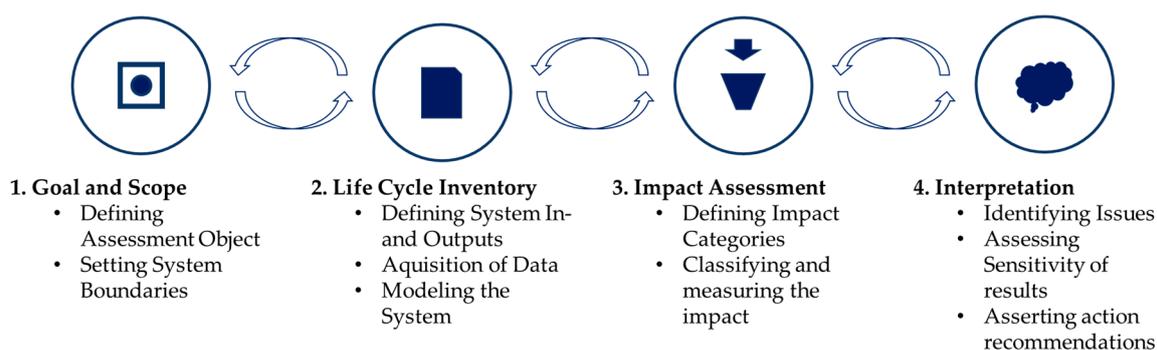


**Figure 8.** Number of positive and negative statements regarding the impact of PSS on sustainability.

It might be possible that a positive publication bias is present in the sample. However, we cannot prove a publication bias statistically (e.g., via a funnel plot) because we do not have the required data. The reason is that reporting of sustainability effects varies greatly at the level of detail and we could, therefore, only record the direction of the effects (positive/negative) but not their strength or reliability as would be necessary, e.g., for a funnel plot [85]. Nevertheless, it can be noted that even the possibility of negative sustainability effects is not discussed in most papers. Thus, it can be concluded that, at least in our sample, the assessment of PSS is significantly positive.

### 3.2.2. Methodological Challenges of Sustainability Assessment for PSS

When assessing the sustainability effects of PSS, a large heterogeneity in the assessment methods used to evaluate the sustainability effects in the papers can be observed. These differences and resulting challenges are discussed below. To put the challenges into perspective we use ISO 14040 and 14044 which describe the common steps for the preparation of a life cycle assessment (Figure 9).



**Figure 9.** Four steps to generate an eco-balance (based on: [86]).

The authors have identified the following methodological challenges in the sustainability assessment of PSS:

- Lack of a methodical approach (relating to Steps 1–4): In some cases, statements on sustainability are derived without a transparent or systematic assessment method. As a result, the evaluation process is sometimes not comprehensible, and the robustness of the results is difficult to assess.
- Lack of a standardized assessment approach (relating to Steps 1–4): If conventional sustainability assessment procedures are used, the execution of the individual steps is non-homogeneous. For example, the choice of system boundaries is diverse and often not defined exactly, which can

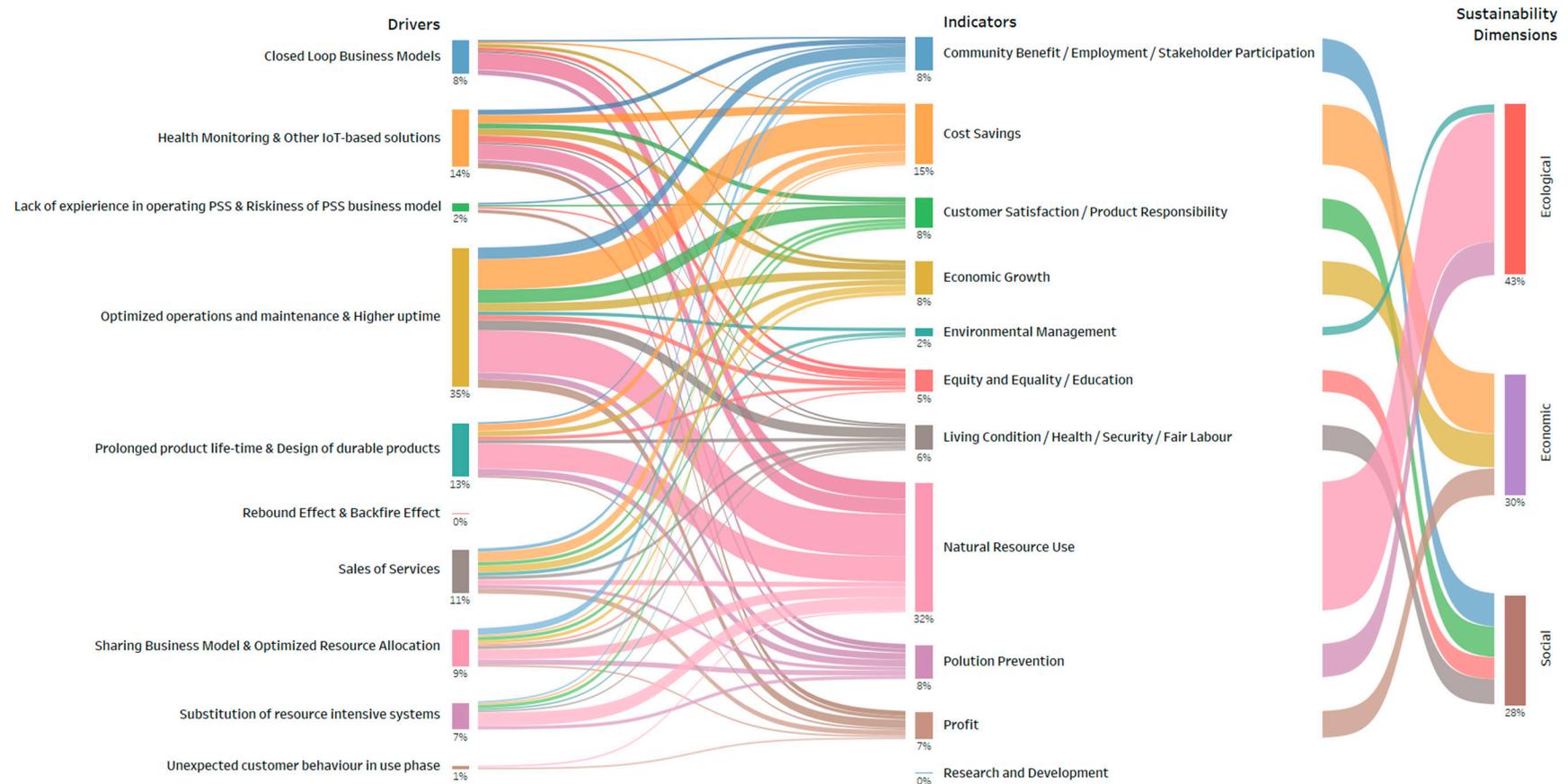
have a major impact on the overall sustainability assessment of PSS. Accordingly, the results are rarely comparable.

- Systematic consideration instead of a singular focus on individual sustainability effects (relating to Steps 1–2): Many papers focus on a specific sustainability aspect, e.g., reducing CO<sub>2</sub> emissions through scooter sharing. As a result, the systemic aspect of PSS has been neglected, which means that any negative sustainability effects that may arise at the same time in another part of the system have not been taken into account, e.g., in the social sustainability dimension, where scooters in sharing business models block footpaths in inner city streets. A systemic approach is necessary.
- Low share of quantitative assessment (relating to Step 3): Only 37% of the papers we examined have a quantitative part in their assessment (e.g. LCA component, evaluation of statistical data). The majority of the data collection focuses on qualitative methods such as interviews and expert workshops. More quantitative research would be desirable for a more objective assessment of sustainability effects.
- Statements without proof (relating to Step 4): In some cases, statements on sustainability effects were made without being able to present corresponding evidence. Accordingly, such statements should be more strongly marked as assumptions or justified with a corresponding explanation.

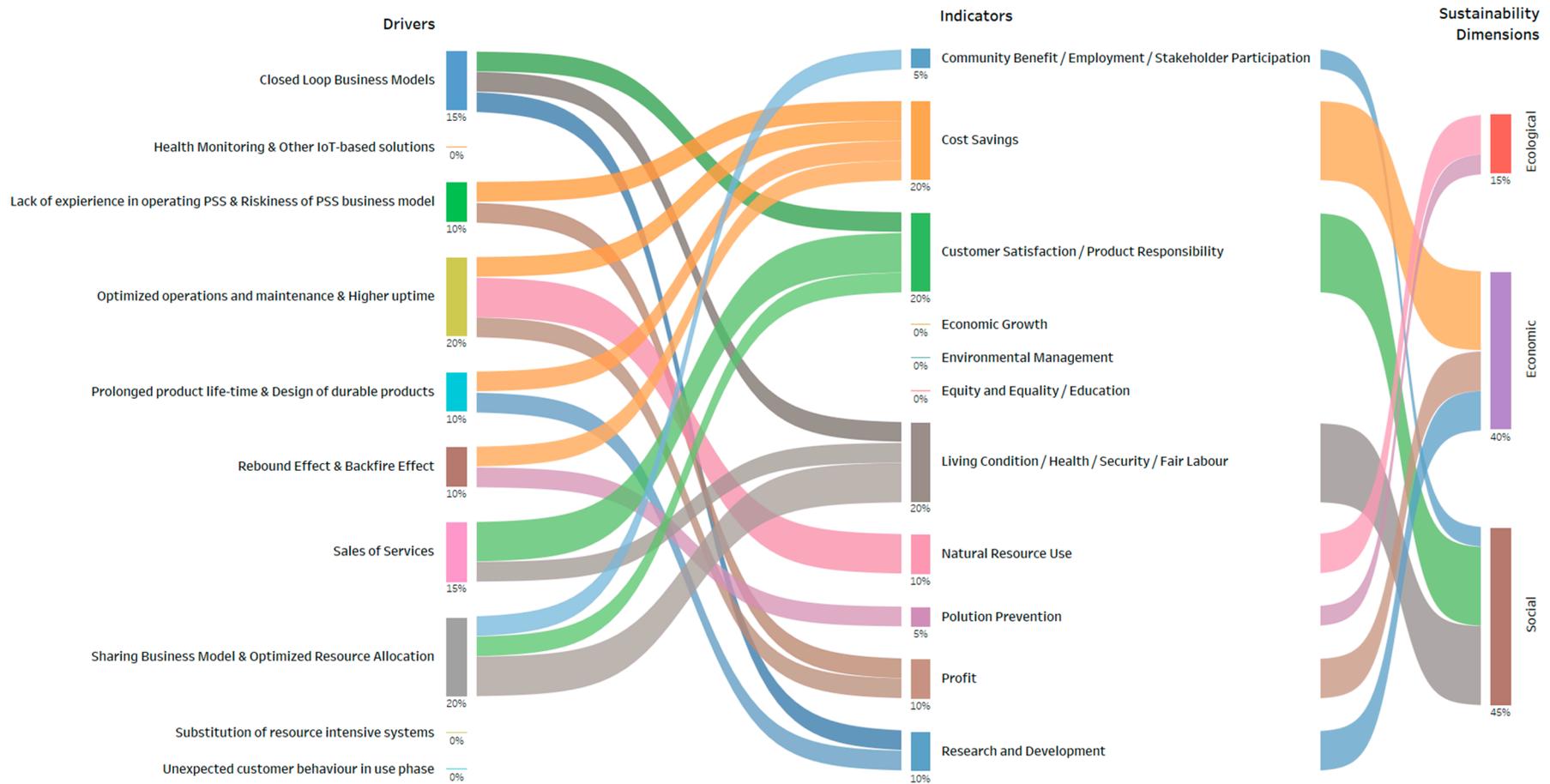
### 3.2.3. Drivers and Indicators of Sustainability in PSS Literature

The decomposition of the statements on sustainability effects of PSS into indicators and drivers allows for a cause-and-effect analysis between drivers and indicators. As the indicators are part of the sustainability dimensions, it is possible to understand which drivers contribute most to which indicators and sustainability dimensions, respectively, according to the reviewed literature. These relationships are shown for all identified positive sustainability effects in Figure 10 and all identified negative effects in Figure 11. The percentages shown in the figures represent the share of the drivers and indicators over their respective sum. For example, it shows that the driver Optimized Operations and Maintenance and Higher Uptime accounts for 35% of all recorded drivers and thus is the largest driver. This can be explained by the fact that improved operation by the manufacturer is one of the key advantages of the PSS approach. Therefore, the frequent appearance of this driver is an expected result. However, it is a very generally formulated driver, so that many sub-aspects can be gathered here. This general formulation was found in many publications, which is why we could not differentiate the driver further. The lack of precision in the description in the literature is therefore also an explanation for the size of the driver.

The flow within the figure highlights relationships between drivers and indicators. If, for example, a paper describes a positive influence of PSS on the indicator Pollution Prevention and attributes this to the driver Closed-Loop Business Models, this is recorded as a relation, that is displayed as a Sankey flow in the figure. The more statements have described this relation, the broader the connecting line from the respective driver to the indicator and sustainability dimension. This enables visual identification of the correlations between drivers and indicators, and indicates the frequency of occurrence in the literature body. In general, it can be stated that among the positive effects, the indicator Natural Resource Use (32%) and hence the Ecological Sustainability Dimension (43%) is considered most frequently in the literature. This corresponds to the general perception that PSS can contribute positively to environmental sustainability. The largest positive driver Optimized Operations and Maintenance and Higher Uptime contributes most to the indicator Natural Resource Use and the economic indicator Cost Savings. In fact, the operation of products by the manufacturer is seen as a competitive advantage in PSS because the manufacturer has special product knowledge. This knowledge enables optimized operation and maintenance, thus avoiding wastage of resources and reduction of pollution.



**Figure 10.** Percentage of statements that relate the respective drivers, sustainability indicators, and sustainability dimensions within the positive effects of PSS on sustainability.



**Figure 11.** Percentage of statements that relate the respective drivers, sustainability indicators, and sustainability dimensions within the negative effects of PSS on sustainability.

With respect to negative effects, economic and social indicators are examined particularly often. The negative aspects of the driver Sharing Business Model and Optimized Resource Allocation are most frequently examined and related to the social indicator Living Condition/Health/Security/Fair Labor. This finding also coincides with the often-discussed conflicts between operators and public authorities in the provision of PSS (e.g., in public spaces with regard to the use of road land). Overall, however, the meaningfulness of the breakdown into drivers and indicators is lower for the negative sustainability effects than for the positive ones, since far fewer statements on this topic can be found in the literature. As described above, only eleven statements on negative effects were found, while 112 statements on positive effects could be identified. A detailed analysis of the results is discussed in the following.

With regard to the positive effects, it is noticeable that the majority of statements refer to ecology (43%), followed by economy (30%), and social aspects (28%). The debate on environmental sustainability of PSS is mainly driven by improved natural resource use (75% of ecological sustainability dimension) and pollution prevention (20% of ecological sustainability dimension), i.e., emissions of greenhouse gases or the discharge of other pollutants into nature. The fact that natural resource use is such a frequently observed sustainability indicator (32% of all indicators) is mainly due to the following drivers:

- **Optimized Operations:** By far the most important driver resulted from the focus of many papers on the improved operation of PSS by the manufacturer, resulting, for example, in less friction in operational processes.
- **Prolonged Product Life Cycle:** It is in many cases considered a driver that PSS suppliers design products for longevity, which saves resources.
- **Closed Loop Business Models:** Here it is often mentioned that PSS providers have the possibility to recycle products at the end of their lifecycle in order to reuse resources.

In pollution prevention (8% of all indicators), the focus was placed in particular on the drivers:

- **Optimized Operations:** Here, many studies emphasize a reference to savings in CO<sub>2</sub> consumption that result from the more efficient operation of PSS.
- **Sharing Business Model:** This driver is highlighted in particular, e.g., by studies that have found improvements in CO<sub>2</sub> emissions through car sharing.
- **Substitution of Resource Intensive Systems:** Studies focus on innovative PSS solutions that could replace existing business models through novel, inherently environmentally sustainable concepts, such as the sale of water treatment systems instead of bottles.

Economic sustainability is largely evaluated using the indicators cost savings (50% of economic sustainability dimension) and economic growth (28% of economic sustainability dimension). For all economic indicators, cost savings (15% of all indicators), economic growth (8% of all indicators), and profit (7% of all indicators), this is mainly due to the following drivers:

- **Optimized Operations:** The papers frequently refer to the possibility of operating PSS more efficiently by the manufacturer, but the analysis also focuses strongly on monetary benefits through cost savings, as well as an improved overall economic growth.
- **Health Monitoring and IoT-based Solutions:** The focus of the papers here is on potential savings through digital technologies, e.g., to perform data-based analysis that lead to monetary savings in the business context.
- **Sales of Services:** This driver describes in the corresponding use cases in particular the nature of long-term service contracts that are independent of economic fluctuations, which would lead to stable revenues from PSS in times of recession. In addition, the sale of services is generally a way to further increase sales volume apart from products.

In the social sustainability dimension, community benefit (30% of social sustainability dimension), which includes stakeholder participation and employee empowerment as well as customer satisfaction

(27% of social sustainability dimension), were the main indicators of positive effects. The indicators equity, equality, and education as well as living conditions, which includes health, safety, etc., were mentioned with an equal magnitude of order. The following drivers were named most frequently for both community benefit (8% of all indicators) and customer satisfaction (8% of all indicators):

- **Optimized Operations:** Here, papers describe the societal benefits of PSS solutions, such as greater participation by involving different stakeholders and the resulting increased customer satisfaction.
- **Health Monitoring and IoT Solutions:** This driver is examined primarily with regard to health care products and the social benefits resulting from this.
- **Sharing Business Model:** The main focus is present in studies that describe how, through car sharing, access to vehicles would also be possible for lower income groups, as vehicles would only have to be paid for temporarily.

The number of statements on negative sustainability effects was almost 10 times lower (Figure 8), so the analysis is accordingly shorter and is primarily reduced in comparison with the results for the positive effects. It is noteworthy that the order with regard to the number of statements in each sustainability dimension is reversed. Negative effects are most frequently described in the social dimension (45%), followed by the economic (40%) and ecological dimensions (20%). This shows that the ecological sustainability dimension is not generally given greater consideration. In the dimension of negative social effects, most of the statements are based on the indicators Living Conditions and Customer Satisfaction (both 20% of all negative indicators), especially due to the following drivers: Sharing Business Model, Sales of Services, and Closed Loop Business Models. The aspect of product ownership as an inherent customer need is therefore a natural issue in sharing business models and thus of particular importance. In the area of economic sustainability, among other things, high risks in the PSS business model are evaluated as drivers for negative effects since they can cause companies to suffer financial disadvantages. In the environmental area, additional operational complexity, such as an extended operational supply chain associated with the provision and operation of PSS were often seen as negative drivers, e.g., for resource use. As mentioned, the direction of these effects is also strongly dependent on the system boundaries chosen for the assessment, so effects in positive and negative directions could quickly reverse with different system boundaries.

#### 4. Discussion

In this section, a conclusion is drawn, an outlook on future research opportunities is given, and then limitations of this literature review are discussed.

##### 4.1. Conclusions

This study examines to what extent the implementation of the PSS approach has led to improvements in sustainability. This allows for a better assessment of the positive and negative effects that can be expected from the introduction of future PSS business models. In particular, the study helps to identify correlations between drivers and sustainability indicators, thus identifying possible blind spots in research. At the same time, we provide an overview of use cases, which serves as an overview of implemented PSS and provides data for future research. Based on the analysis of use cases from 62 papers, we were able to establish that a predominant number of reported sustainability effects are assessed positively. In particular, ecological benefits in the areas of natural resource use and pollution prevention of PSS are highlighted. Thus, PSS could indeed be a form of future business model that helps to limit, for example, climate change. Furthermore, the positive economic effects of PSS are often pointed out, which especially contribute to cost savings. Therefore, companies should consider PSS business models also regarding potential economic benefits. Among the drivers, Optimized Operations and Higher Uptime, as well as Health Monitoring and other IoT-based Solutions are particularly important drivers for sustainability effects of PSS. This suggests that with the general increase in digitalization these drivers will become even stronger in the future, so that it can be assumed

that more PSS business models could be introduced in the future, which could lead to improved sustainability. However, negative effects in particular have not been given much attention, which is also a possible explanation for the fact that many companies are still hesitant to introduce PSS business models. A stronger consideration of negative effects could enhance the knowledge of potential risks and enable companies to react accordingly, so that uncertainty is removed and more PSS could be introduced. In addition, this literature review also underlines the necessity to consider sustainability as early as possible in the development and creation of PSS. Without assessing the impact on ecological, economic, and social indicators, positive sustainability effects of the PSS cannot be predicted with certainty. The possibility to collect data for sustainability assessment is theoretically available, but it has to be planned systematically during the development of new PSS, so that all necessary elements of data collection, transfer, analysis, and interpretation can be implemented from an early stage. This includes the development of the necessary hardware and software, as well as the design of the operations. Particularly often, systemic interrelationships of PSS are disregarded. The goal should be to evaluate and optimize the sustainability effects of PSS in all sustainability dimensions over the entire system and its whole lifecycle from production through operation to disposal. Today, this holistic consideration is neglected in many cases.

#### 4.2. Research Proposals

The findings of our literature review directly result in suggestions for future research on sustainability effects of PSS, which are presented in the following.

1. The development and application of a standardized method for the assessment of sustainability effects of PSS is necessary. In particular, guidelines for the consistent choice of system boundaries could provide a positive impact. This would help to increase the comparability of the sustainability effects of PSS and set a standard so that a positive or negative sustainability assessment cannot be influenced by the arbitrary choice of system boundaries.
2. Moreover, standardized procedures should be developed and applied more widely, placing greater emphasis on quantitative approaches in order to increase data-based evidence. This could improve the accuracy and objectivity of sustainability assessments. In addition, the possibilities for data-based analysis increase due to innovations in IoT-technologies, which is why this research approach is particularly promising for the future.
3. In addition, a stronger discussion of negative sustainability effects should also be encouraged. Without the in-depth consideration and analysis of negative effects of PSS on sustainability, many companies are still uncertain about the potential risks of introducing PSS. These dangers can materialize in all dimensions of sustainability and should therefore be extensively examined in the future. In this context, the analysis should also include approaches on how to deal with these risks.
4. In this context, another research gap that arises directly from the presented analysis, is the examination of a possible publication bias. It is important to clarify whether the reported positive sustainability effects are actually due to the PSS business model or whether a corresponding bias is proportionally reflected in the results.

Overall, based on the literature, we found evidence that PSS could have substantial positive effects on sustainability, especially in the environmental sustainability dimension. However, the research field of use case-based assessment of sustainability effects of PSS is still underdeveloped and more studies with a more data-based approach are needed in the future. In total, only 40 papers in the search process dealt with existing PSS business models. Even though the number of implemented PSS business models is still comparatively low in practice, studies should examine existing PSS more closely in order to learn from them and to guide other companies a path towards sustainable PSS.

### 4.3. Limitations

The results are limited in their meaningfulness by the following elements. The literature body itself is a limiting factor, since only a narrow sample size could be investigated. Here it is necessary to add further papers from additional databases and from grey literature in order to investigate further industries and applications. Furthermore, despite a methodical approach to tagging, we are subject to a certain degree of subjectivity, since, e.g., statements were partly unclear and hence subject to interpretation. Therefore, in the future, literature analyses based on algorithms could be performed to further increase the objectivity and traceability of judgements. In addition, the description of use cases in the papers is too heterogeneous, so that our analyses are conducted on paper level and not on use case level. For more refined analyses it would be necessary to further narrow down the selection criteria when compiling the literature body in order to achieve a better data set. As a consequence, here exists a clear need for additional databases as described above. Finally, we could only look at the direction of sustainability effects, but not at their quantitative impact or accuracy. Here, it would be desirable to carry out studies that can provide insights on the magnitude of sustainability effects of PSS.

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