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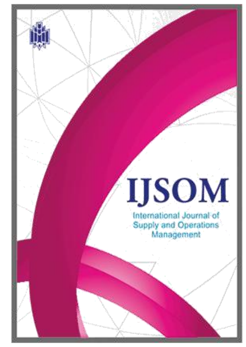

Cost Analysis in Product-Service Systems: A Systematic Literature Review

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Abstract

This paper delves into the cost analysis methods of Product-Service Systems (PSS). With Earth's limited resources and the rise of systems like the circular economy, the development of product-service systems, as exemplars of sustainability-driven servitization solutions, is inevitable. By reviewing subject areas related to cost analysis in product-service systems literature published in quality journals, this study aims to identify and discuss current themes, how cost analysis is addressed in different PSS business model implementation tactics, and propose areas for future research. In this research, a narrow but in-depth bibliometric analysis of product-service systems cost analysis has been conducted. By examining research relevant to the scope of this paper, some primary areas for future research including value-based pricing using utility theory, calculation of Eco-Cost Value, and utilizing simulation models for uncertainty management, have been extracted. A narrow but in-depth bibliometric analysis of product-service systems cost analysis can add value to the future development of this research area by recognizing leading scholars in the field.

Keywords: Product Service System; Cost Analysis; Systematic Literature Review; Bibliometric Analysis.

1. Introduction

Servitization is the practice of sellers enhancing their sales of physical products by providing supporting services. In adopting servitization, manufacturing companies combine product offerings with related services that are specifically adapted to customers' requirements. The business value of servitization grows as services are incorporated, making it a noteworthy trend in contemporary manufacturing industries, supported by a rising number of studies (L. Liu et al., 2021).

Servitization can take several forms, one of which involves offering services that refurbish or renew customers' used products to an almost original condition, often referred to as "refresh services". These refresh services are interconnected with three viewpoints considered in literature, including, servitization, remanufacturing, and product maintenance (Pangburn & Stavrulaki, 2022). Servitization extends to various business initiatives, including Product-Service Systems (PSS). The intensifying global competition and heightened customer expectations have prompted manufacturers to undergo a shifting from a product-centric approach to a service-oriented model. This shift involves not only changing business strategies but also expanding and aligning product portfolios toward value-creation chains. Manufacturers aim to maximize profitability and foster customer loyalty by integrating products and services into a cohesive solution known as PSS (Song & Sakao, 2018; Shen et al., 2017; Lindahl et al., 2014; Datta & Roy, 2010).

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PSS represent a modern business framework blending physical goods and non-material services to address customer needs. It entails companies combining products with services to effectively deliver functionalities that replace tangible items. Rooted in stakeholder interactions emphasizing the triple bottom line, i.e., economic, social, and environmental dimensions, PSS endeavors to bolster the sustainability of enterprises (Kuo et al., 2019; Nurhadi et al., 2017).

Manufacturing firms should transition into services, as services offer a new revenue stream, particularly crucial for companies with products characterized by long life cycles. Loyal customers of such products prove to be more profitable than acquiring new customers. PSS is crafted as a comprehensive solution offered by the original equipment manufacturers, making it challenging for customers to typically separate components of the PSS and procure them from alternative suppliers (Datta & Roy, 2010).

The shift toward service-focused manufacturing models has prompted companies to move progressively from traditional product production to the delivery of integrated services (Zhang et al., 2020). PSS are characterized by the extension of service offerings throughout the product lifecycle. The growing adoption of PSS-based business models has created new pressures for conventional firms, driving them to formulate innovative strategies in order to remain competitive. Integrated product-service systems incorporate a broader range of functions through integrated services, offering higher value compared to conventional products with defined functionality.

The manufacturing sector has experienced a notable shift with the swift adoption of smart technologies, giving rise to a new smart PSS paradigm that responds to mass personalization and global market competition. The trend of globalization has fostered a seamless integration of products, services, sensors, and the Internet. This has driven a transition from traditional product-centric models to PSS, enabled by IoT-integrated solutions. These solutions enable the creation of value through services across various parts of the network (Chen et al., 2020; Osako et al., 2019).

PSS represent a hybrid offering that combines both products and services, and can be examined from various perspectives, including cost considerations (Song & Sakao, 2018). In comparison to pure physical products, PSS places emphasis on the use value throughout its entire life cycle, particularly evident in complex PSS scenarios involving intricate products with extended service life. Evaluating the use value of PSS is essential, with Life Cycle Cost (LCC) serving as a key indicator that accounts for all costs from capturing customer requirements to product disposal and recycling (Schneider et al., 2022; Wang et al., 2022; Marchi et al., 2016).

Due to the extensive scope of PSS, calculating the whole lifecycle cost of a PSS is a complex task. Additionally, considering its socio-technical nature, PSS faces challenges such as the inability to address a single cost object (which could be any products, customers, departments, projects, activities, etc., for which costs are measured and assigned) at a time. It remains challenging to control cost and performance fluctuations throughout organizational processes and to accurately allocate costs to specific activities (Settanni et al., 2014).

As companies strive for improvement and intensify competition on cost, manufacturing activities tend to gravitate toward lower-cost directions, leading to an expansion of offerings that now include both pre- and post-production services. Consequently, relying solely on product-based advantages is becoming increasingly difficult. Research on PSS costing has largely concentrated on developing methods to address challenges such as limited data, lifecycle representation, and uncertainty modeling. In contrast, there has been comparatively little focus on analyzing the inherent nature of PSS costs and how they differ from traditional product- or service-cost frameworks. Settanni et al. (2014) classified challenges in PSS costs into three categories: Suitable cost object(s) (What?), Objective, limitations, and extent (Why/To what extent?), and Calculations and measurements (How?)

Despite efforts to integrate research on product-service systems, a literature gap persists, hindering the attainment of a comprehensive understanding of cost analysis in this domain. The existing knowledge on product-service systems cost analysis is currently fragmented, lacking clarity because of this research gap. Considering these observations, the following research question arises:

RQ1: Who are the key sources, publications, and contributors, and what are their relationships within the literature on cost analysis of PSSs?

RQ2: What are the prominent thematic areas that emerge from the literature on cost analysis of PSSs?

RQ3: How can the literature on cost analysis of PSSs be advanced based on insights from previous research?

This paper aims to explore the cost analysis of PSS by offering a comprehensive overview of existing methodologies and highlighting the challenges associated with such analyses. To achieve this objective, we employ a systematic literature review methodology to categorize findings and elucidate operational-level strategies employed by companies in implementing their business models.

Our investigation addresses three key Research Questions (RQs). RQ1 is addressed through bibliographic analysis, while RQ2 is tackled by conducting content analysis of selected articles to identify major thematic areas within the literature. Furthermore, we respond to RQ3 by presenting brief discussions on prior research and delineating actionable future research agendas based on classification from various perspectives.

This study contributes to the field by consolidating fragmented literature on the cost analysis of PSSs, offering valuable insights for managerial decision-making, and inspiring future academic research endeavors.

The remainder of this paper is structured as follows: Section 2 outlines the most relevant literature. Section 3 presents the methods used for review. Section 4 is devoted to the results. Section 5 provides a discussion, and conclusions based on the findings are provided in Section 6.

2. Literature review

During the research process, we identified and selected the research studies of Rodríguez et al. (2020), Bertoni and Bertoni (2020), and Datta and Roy (2010) to be considered as related research. These studies were selected as they align closely with the scope and methodology of the present research, while their distinguishing features are summarized in Table 1.

To begin with, it should be noted that the reviewed studies were published during the period from 2010 to 2020. Furthermore, each of these works places a strong emphasis on assessing Product–Service Systems (PSSs) from a cost analysis perspective. While Rodríguez et al. (2020) provides a comprehensive description of the PSS Cost Estimation Process derived from an Integrative Review of Literature, Bertoni and Bertoni (2020) develop a Life Cycle Cost (LCC) estimation framework utilizing concept design simulations to investigate the feasible design space within Computer-Aided Engineering. Additionally, Datta and Roy (2010) identify areas for future research in availability-type service support contract cost estimation through a structured literature review.

To the best of our knowledge, no prior study has offered a comprehensive investigation into PSS cost analysis that also integrates a bibliometric perspective.

Table 1. Related research.

Authors (year)	Research aim	Methodology	Time horizon	Reviewed papers	Database	Field	Focus
Datta & Roy (2010)	explores availability type service support contract cost estimation	Str. LR	1990–2009	53	Scopus & WOS	Defense organizations	Design
Rodríguez et al. (2020)	Comprehensive description of PSS cost estimation process	Int. LR	2008–2017	39	WOS, ProQuest, Scopus, Web of Knowledge, EBSCO, and Google Scholar	Generic	Contract
Bertoni & Bertoni (2020)	Gather existing contributions in the field of PSS cost engineering	SLR	2005–2017	19	Scopus	Generic	Design
This paper	Exploring current themes and how cost analysis is addressed in different PSS business model implementation tactics	SLR	2000–2023	54	Scopus & WOS	Generic	Life cycle

Note: Str. LR (structural literature review); Int. LR (Integrated literature review); SLR (systematic literature review).

To conduct this research, we employed the method of systematic literature review as outlined by Moher et al. (2009). Flow diagram of the review process is illustrated in Figure 1.

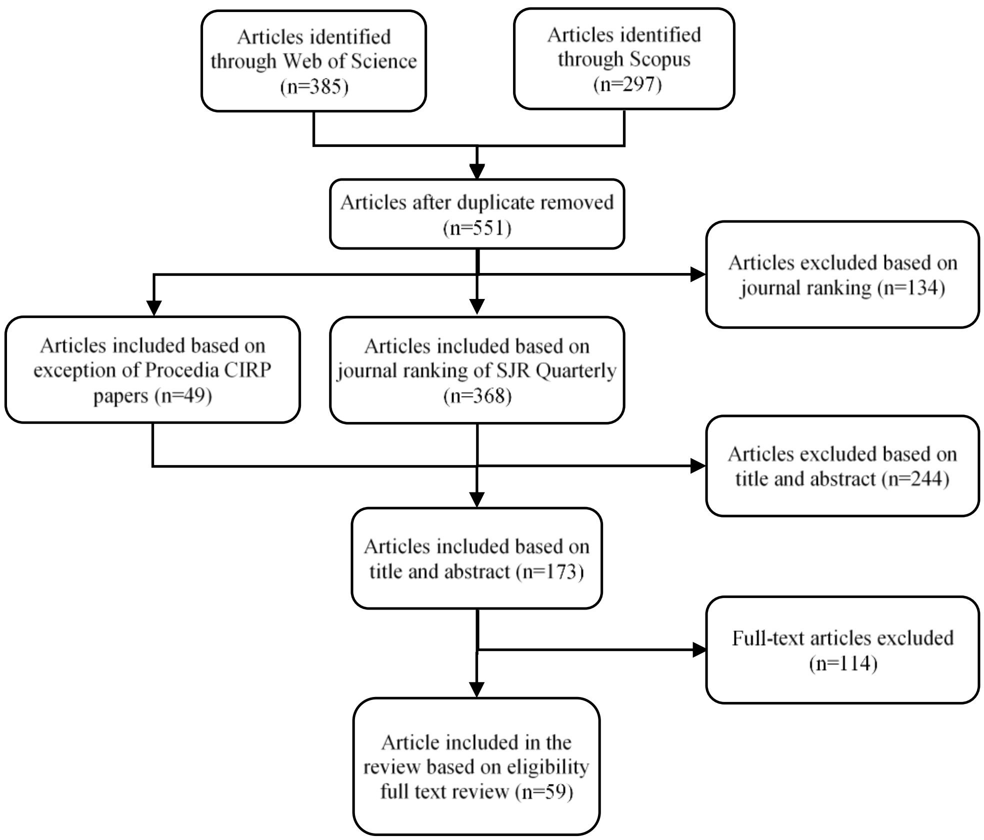

Figure 1. Screening process, based on the PRISMA flow diagram (Moher et al., 2009).

3. Results

As depicted in Figure 1, the initial data collection identified a total of 546 publications. Following the screening stage, 59 studies were deemed relevant to the objectives of this research.

Furthermore, an observation from the data reveals a notable increase in the industry sector's interest, aligning with expectations over the years. The reviewed publications range from 2010 to 2023, with more than half appearing within the past six years. Two notable periods of increased research activity were observed during 2016–2017 and 2018–2020. The 546 investigated publications were sourced from 22 different outlets. Top 10 of the most relevant sources are depicted in Table 3.

Building upon the subject classifications provided by Elsevier's Scopus database and taking into account citation counts per publication, strong research engagement with this topic is evident within the fields of Industrial and Manufacturing Engineering and Management Science and Operations Research (refer to Table 4). Furthermore, examining the ten most frequently cited studies confirmed this finding, since each of them falls within these same subject categories (refer to Table 5). The occurrences of the Top 10 Author Keywords are illustrated in Table 6.

Table 2. Main information about selected papers.

Description	Results
Main Information About Data	
Timespan	2010:2023
Sources (Journals, etc.)	22
Documents	59
Average years from publication	4.04
Average citations per documents	20.09
Average citations per year per doc	2.959
References	2450
Document Types	
Article	44
Conference paper	14
Review	1
Document Contents	
Keywords Plus (ID)	453
Author's Keywords (DE)	212
Authors	
Authors	180
Author Appearances	201
Authors of single-authored documents	2
Authors of multi-authored documents	178
Authors Collaboration	
Single-authored documents	3
Documents per Author	0.323
Authors per Document	3.09
Co-Authors per Documents	3.61

Table 3. Top 10 of the most relevant sources.

Sources	Articles	Total citations
Procedia CIRP	14	155
Journal of Cleaner Production	8	333
International Journal of Production Economics	5	118
Sustainability (Switzerland)	4	45
CIRP Journal of Manufacturing Science and Technology	3	122
European Journal of Operational Research	3	27
International Journal of Production Research	3	77
International Journal of Advanced Manufacturing Technology	2	150
Production Planning and Control	2	45
Resources Conservation and Recycling	2	25

Table 4. Top 5 Subject areas of source of publications according to Elsevier's Scopus.

Subject area	No. of publications
Environmental science	27
Management science and operations research	16
Strategy and management	12
Environmental science	10
Renewable energy sustainability and the environment	10

Table 5. Top 10 the most global cited documents (The number of citations a document has received globally).

Paper	Total Citations	Citations per year
Lindahl et al. (2014)	171	19
Datta & Roy (2010)	112	8.615
Erkoyuncu et al. (2011)	106	8.833
Settanni et al. (2014)	64	7.111
Schröder et al. (2015)	63	7.875
Song & Sakao (2018)	45	9
Greenough & Grubic (2011)	40	3.333
Erkoyuncu et al. (2013)	36	3.6
Sakao & Lindahl (2015)	34	4.25
Zhang et al. (2018)	32	6.4

Table 6. Top 10 author keywords by occurrences.

Words	Occurrences
Product-service systems (PSS)	25
Life-cycle cost (LCC)	13
Servitization	11
Pricing	10
Cost estimation	7
Total cost of ownership	6
Uncertainty	6
Sustainability	4
Sharing economy	3
Circular economy	3

Graph theory examines graphs, which are mathematical constructs representing relationships between pairs of entities. A graph is composed of vertices, also referred to as nodes or points, that are linked by edges, sometimes called lines or connections. In the interpretation of network analysis plots, factors such as centrality/periphery (position), bubble dimension (citations), strength of relationships (links), clusters (and density), and bridges are considered. For Co-occurrence network analysis of terms, we selected the VOSviewer software. The results of the network analysis are depicted in Figure 2. Larger circles indicate more frequently occurring terms, closely related terms are grouped by color, and the distance between terms reflects the strength of their association, as computed by VOSviewer software (Version 1.6.18). The network analysis revealed three clusters: 'lifecycle,' 'cost,' and 'profitability.' These clusters were represented by terms such as 'lifecycle cost,' 'product design,' and 'decision making' for 'lifecycle'; 'cost accounting,' 'servitization,' and 'uncertainty analyses for 'cost'; and 'pricing strategy' and 'maintenance' for 'profitability' (red= 'lifecycle,' green= 'cost,' blue= 'profitability'). Notably, the clusters and terms identified through network analysis aligned with the searched keywords and the subject-area analysis of the sources within the dataset. The social structure of the analyzed collections reveals how authors are interconnected in the scientific research field. One prevalent form of social structure is the co-authorship network, which can unveil various insights such as groups of regular authors, influential authors, hidden author communities, and relevant institutions in specific research fields. The co-authorship network for the analyzed collections is visualized in Figure 3.

Table 7 presents an overview of the theories identified in the reviewed publications, along with their frequency of occurrence. Notably, 40 of the 54 publications reference at least one theory. Moreover, it is evident that the 'Uncertainty Theory' holds a dominant position in the selected publications. In line with the research objectives, 'Decision Support Theories' emerge as the most prominently represented, with an emphasis on guiding PSS business model decisions through cost analysis.

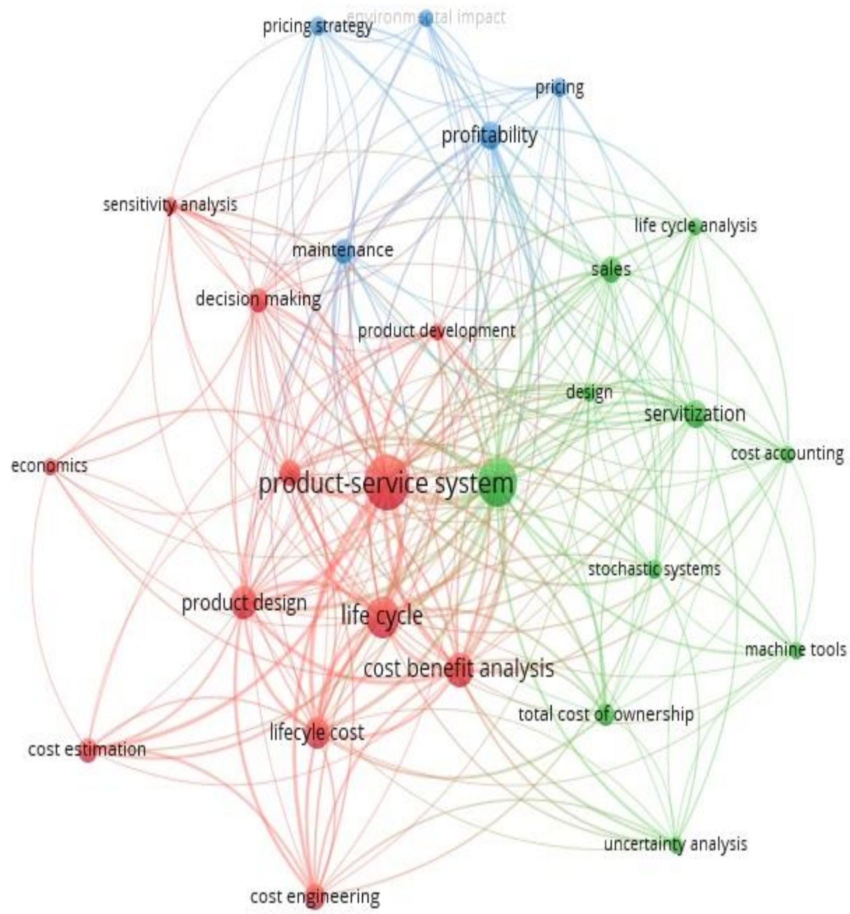

Figure 2. Co-occurrence network analyses of most frequent terms in title and abstract (VOSviewer Version 1.6.18).

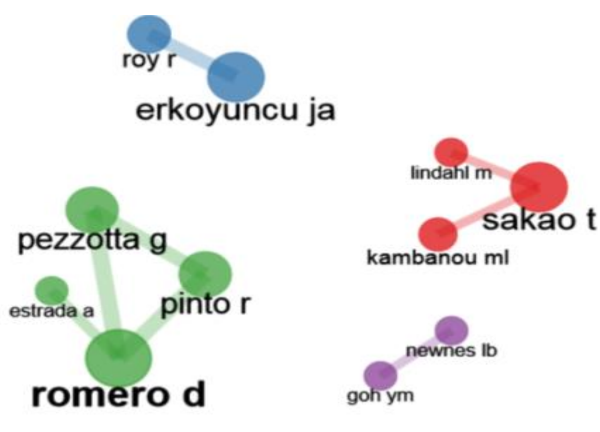

Figure 3. Co-authorship network.

Table 7. Mentioned theories of the selected publications.

Mentioned theory	Num. of publications mentioned the theory
Uncertainty theory	8
Discrete event simulation	4
Game theory	4
Regression analysis	4
Multi-criteria decision-making theory	4
Decision-Making and Trial Evaluation Laboratory (DEMATEL)	3
Risk theory	2
Utility theory	2
Agency Theory	1
Agent Based Simulation	1
Bayesian network	1
Interval possibility method	1
Mass customization	1
Markov processes	1
Monte-Carlo simulation	1
Multi-objective stochastic programming	1
Pricing Theory	1
Rough-Fuzzy DEA	1
Stochastic dynamic programming	1
Stochastic Process	1
System thinking	1

4. Discussion

Economically, PSS most commonly employs tools such as cost estimation, net present value for forecasting economic potential, cost–benefit analysis, and qualitative assessments like the potential for new market development.

Cost estimation offers critical information to diverse stakeholders and, as a management tool, is referred to as a 'should-cost.' It represents a one-time figure, typically approved for specific purposes such as budgeting (Settanni et al., 2014). In addition, when applied as a management system, cost estimation becomes an ongoing process in PSS management and is often termed a 'strategic estimate'.

In the context of PSS as a socio-technical 'system' delivering value in-use, there are multiple interacting cost objects. Because PSS involve multiple interconnected and interacting cost objects, examining them individually does not yield an accurate estimation (Bertoni & Bertoni, 2020).

It is recognized that qualitative and quantitative methods of cost estimation must be employed together, with quantitative methods offering a mathematically treatable counterpart of a qualitative PSS representation (Settanni et al., 2014).

Manufacturers in developed countries face growing pressure to reduce costs from the market and minimize environmental impacts from society (Sakao & Lindahl, 2015).

PSS costs are typically defined by monetary outflows over time, reflecting the asset's use phase.

Within the PSS context, beside the product's short-time access fee, costs also include sharing-related transaction costs (the effort, time, and costs incurred in searching, creating, negotiating, monitoring, and enforcing a service contract between buyers and suppliers) and emotional costs, due to perceived risks (i.e., uncertainty about whether the required resource is accessible) (Akbar & Hoffmann, 2018).

Costs driven by both product and service features compose variety-induced costs of PSS, which require different calculation approaches (Schuh et al., 2017).

A PSS cost element is a fundamental unit for conducting PSS costing, representing resources consumed in delivering service activities or product functions. The three-dimensional PSS cost element is defined by the cost incurred by a 'resource,' executed through a 'process,' and associated with a specific 'PSS entity' (Shen et al., 2017).

In the PSS context, companies underestimate the cost of their offerings, which is because of the inability of a company to represent its causal mechanisms' behavior using cost metrics (Settanni et al., 2013). Consequently, manufacturers frequently struggle to make appropriate decisions, such as setting contract prices.

4.1. PSS Implementation Tactics

Content analysis of the selected articles indicates that PSS cost analysis and implementation implications are generally addressed through five distinct sets of tactics proposed by (Reim et al., 2015). After deciding on the company's business model to apply, tactics are identified as the company's residual choices at an operational level.

- PSS Contract Tactic (refer to Table 8):

Contracts define the responsibilities of a PSS provider and its customer during a specific contractual period. All aspects related to providing the service and stating the rights and liabilities of involved parties are clearly defined by contracts.

The co-creation of value in PSS relies heavily on both supplier profitability and customer affordability. Consequently, it is imperative to assess the uncertainty in cost estimation rigorously during the bidding stage to accurately gauge these metrics (Erkoyuncu et al., 2011).

The intricacy of a contract corresponds to the volume of regulations stipulated within it. Consequently, while all legal contracts are inherently complex, the degree of complexity varies depending on the category of PSS business model employed.

Moreover, fostering a sustainable, long-term relationship between provider and customer, based on the PSS contract, is essential. Therefore, meticulous handling is required to effectively balance the interests of both parties. PSS literature emphasizes the need to carefully assess risks and provide adequate compensation to the party bearing them.

Table 8. The relationship of PSS cost analysis and PSS contract tactic.

Authors, year	**Research purpose**	**Contribution**	**Application**	**Theory**	**CEM**
Jackson et al. (2023)	A decision-making framework for contract pricing, airline engagement quantification, and contract preference selection.	T, M	Aviation	Decision making	PM
Guzzo et al. (2022)	Development of a pricing system for result-oriented PSS, structured around machine LCC components comprising fixed and variable costs.	M, E	Automotive	NM	PM
Jackson & Pascual (2021)	Methodology for determining maintenance policies outsourced to external agents, concurrently negotiating service contract fees.	M, E	Numerical case	Game theory & Stochastic process	PM
Deprez et al. (2021)	Establishment of a data-driven maintenance tariff plan utilizing predictive models that account for diverse machine profiles.	T, M	NM	Risk theory	PM
Farsi & Erkoyuncu (2021)	Framework for quantifying stochastic uncertainty in cost-benefit analysis of PSS contracts, employing a bottom-up costing approach through agent-based simulation.	M, E	Machine tool	Agent based simulation	PM
Datta (2020)	Development of a framework that links hidden cost drivers, PBC life cycle stages, and engagement of service network partners.	T, E	Defence	Agency theory	NM

Authors, year	Research purpose	Contribution	Application	Theory	CEM
Rodríguez et al. (2020)	Detailed exposition of the PSS Cost Estimation Process derived from an Integrative Literature Review.	M	NM	Uncertainty theory	NM
Zhang et al. (2020)	Examination of the influence mechanism of enterprises' uncertain demand on profit decisions regarding WPSS.	M	Warehouse	Interval possibility method	PM
Roda et al. (2020)	Development of a comprehensive methodology for constructing asset-centric, performance-driven Total Cost of Ownership (TCO) models to facilitate decision-making.	M, E	Chemical	Decision making theory	NM
Mu et al. (2017)	Design of a coordination decision support model employing Stackelberg game theory for machine tool-industrial Product-Service Systems (mt-iPSS).	M, E	Printing	Game theory	PM
Saccani et al. (2017)	Creation of a universal model for evaluating the Total Cost of Ownership (TCO) of durable consumer goods such as cars and household appliances.	M, E	Household	NM	EA
Nurhadi et al. (2017)	Introduction of a novel approach for assessing sustainability impacts and TCO variations among business models of private cars using different energy sources.	M, E	Carpooling & Leasing	NM	PM
Kyösti & Reed (2015)	Implementation of a decision-making tool that forecasts costs associated with supporting Full Maintenance contracts through discrete event simulation modeling.	T, M, E	Numerical case	Discrete event simulation	PM
Kreye et al. (2014)	Development of a conceptual framework illustrating the impact of uncertain factors on bidding strategies based on empirical studies.	M	NM	Uncertainty theory	NM
Settanni et al. (2014)	Formulation of a methodology for Total Lifecycle Cost (TLC) analysis addressing challenges in PSS cost assessment, including cost objects, scope, and computational methods.	T, M	NM	NM	NM
Erkoyuncu et al. (2013)	Utilization of a soft system approach to identify uncertainties during the bidding phase of service contracts, affecting both cost and performance.	M, E	Defence	Uncertainty theory	NM
Romero Rojo et al. (2011)	Establishment of a cost estimating framework tailored for Electrical and Electronic Equipment (EEE) components, a primary source of obsolescence issues.	M, E	Defence	Uncertainty theory	EA & PM
Datta & Roy (2010)	Identification of future research directions in availability-type service support contract cost estimation through a structured review of literature.	M, E	Defence	Uncertainty theory	NM

CEM: Cost Estimation Method, EA= Estimating by analogy, IM= Intuitive method, PM= Parametric method, ABC= Activity-Based Costing, NM=Not mentioned; Type Of Contribution: T=Theoretical, M=Methodological, E=Empirical

- PSS marketing tactic (refer to Table 9):

The PSS marketing tactics explain how PSS providers engage with customers, convey the offered value, and leverage customer and market knowledge to operationalize their PSS business model (Reim et al., 2015).

At the end of the lease, manufacturers face a challenging decision between investing in additional durability and the product's residual value, weighing whether to lease or sell it. This challenge involves three key factors: technological innovation, maintenance level, and acceptance in the second-hand market (Kuo et al., 2019).

From a marketing aspect, PSS customization complicates customers' ability to compare it with alternative solutions (Datta & Roy, 2010).

Industries face constant pressure to enhance both profitability and customer satisfaction. In PSS, it is essential to optimize the design of a product and make its service flexible and integrated (Farsi & Erkoyuncu, 2021).

Any aspect that includes customer beliefs, like customer utility, is involved in PSS marketing tactics.

Table 9. The relationship of PSS cost analysis and PSS marketing tactic.

Authors, year	Research purpose	Contribution	Application	Theory	CEM
Sai et al. (2023)	Assessment of the environmental repercussions of product-service systems within the digital devices market.	E	NM	NM	-
Arani et al. (2022)	Exploration of optimal profit-maximizing pricing strategies for servicizing business models, taking into account consumer welfare and environmental implications.	T	NM	Game theory	PM
Pangburn & Stavrulaki (2022)	Development of an analytical model to determine optimal prices and quantities for a firm offering product-refresh services alongside new product releases.	T	NM	Utility Theory	PM
Zhang et al. (2021)	Investigation into the configuration challenges of product-service systems based on customer requirements and uncertain customer behavior, incorporating service utilities and price sensitivity.	M	Numerical case	Multi-objective stochastic programming & Utility theory	PM
Z. Liu et al. (2021)	Construction of an analytical framework to identify factors hindering manufacturers from offering sharing services.	T, M	Numerical case	Pricing theory	PM
Xu et al. (2020)	Formulation of a multi-period joint pricing and inventory management problem using stochastic dynamic programming.	T	NM	Stochastic dynamic programming	PM
Song & Sakao (2018)	Introduction of a method for recommending product-service systems considering their environmental impact, utilizing rough DEMATEL to manage the interactions of ambiguous user preferences.	M, E	Elevator company	Multi-criteria decision-making theory	NM

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- PSS network tactic (refer to Table 10):

The PSS network tactic describes how PSS providers, according to the type of partners, use their network relationships with external partners to accomplish sharing and coordinating activities. A network represents the relationships and interactions among various external stakeholders (Reim et al., 2015).

Based on the PSS business model, there are different types of partners and types of relationships in the network structure. For example, dealers and providers act as intermediaries between the manufacturer and the customer, or a third-party provider may perform a related service task or may be in direct contact with the customer through dealers or providers.

Cost categories related to inventory costs, replacement costs, in-use product costs, and maintenance costs are involved in the PSS network tactic.

Table 10. The relationship of PSS cost analysis and PSS network tactic.

Authors, year	Research purpose	Contribution	Application	Theory	CEM
Zhang et al. (2023)	A comprehensive reference for enterprises detailing the planning, establishment, selection, implementation, and maintenance of service offerings for customer-product interaction life cycles in smart Product-Service Systems (PSS).	T, M	Automotive	Decision making	PM
Schneider et al. (2022)	An approach to quantifying the impact of transport costs within a maintenance network on the Life Cycle Cost (LCC) of Product-Service Systems (PSS).	M	NM	NM	PM
L. Liu et al. (2021)	Development of an analytical model for competing in a module-product-based service mode where manufacturers integrate with suppliers in the supply chain.	T, M	Numerical case	Game theory	PM
Kaddoura et al. (2019)	Assessment of the feasibility of implementing PSS for passive products through Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and examination of environmental and economic outcomes in five real case studies.	E	Manufacturing	NM	EA & IM
Liu et al. (2019)	Implementation of a discrete-time Markov Decision Process for devising maintenance policies aimed at maximizing the provider's long-term revenue.	T, E	Numerical case	Markov processes	PM
Osako et al. (2019)	Discussion of the distinctions between traditional time/use-based maintenance and IoT-enabled maintenance cost models.	M, E	Machinery	NM	NM
Guo et al. (2019)	Formulation of a pricing model combining service-oriented, cost-oriented, and competition-oriented pricing theories in PSS maintenance.	T	NM	Regression analysis & Pricing theory	PM
Estrada et al. (2017)	Development of a PSS cost-engineering method based on stochastic process modeling.	M, E	Bike-sharing system	Discrete event simulation	ABC & PM
Seiringer & Bauer (2016)	Presentation and evaluation of a costing approach for PSS, incorporating risk factors associated with the reliability of customer input.	M, E	Repair	Risk theory	ABC
Estrada & Romero (2016)	Establishment of a Cost Engineering Method for PSS based on System Cost Uncertainty Analysis (SCUA).	M	NM	Uncertainty theory	PM
Marchi et al. (2016)	Evaluation of a solution comprising an electric transformer and intangible services tailored to meet operational requirements.	M, E	Electric transformer	NM	PM
Schröder et al. (2015)	Examination of a business model assessing process costs of additive manufacturing technologies.	M, E	Printing	NM	ABC
Erkoyuncu et al. (2011)	Proposal of components for a service delivery system and classification of uncertainty sources based on literature findings.	T	NM	Uncertainty theory	NM
Greenough & Grubic (2011)	Exploration of the relationship between Prognostics and Health Management (PHM) technologies and servitization, illustrated through the description of two software tools.	E	Aerospace	Discrete event simulation	PM

CEM: Cost Estimation Method, EA= Estimating by analogy, IM= Intuitive method, PM= Parametric method, ABC= Activity-Based Costing, NM=Not mentioned; Type Of Contribution: T=Theoretical, M=Methodological, E=Empirical

- PSS product and service design tactic (refer to Table 11):

PSS design describes how products and services are designed to meet the diverse requirements of stakeholders (e.g., customer needs) to successfully implement PSS business models. It has two aspects: The functionality dimension refers to the design of the product or service to maximize value for customers, whereas the customization dimension pertains to the degree to which offerings are adapted to meet the specific needs of individual customers (Reim et al., 2015).

PSS characteristic design is a critical aspect in PSS planning. The constraint satisfaction problem (CSP) is used to model the feasible design schemes of PSS characteristics and their constraints (Wang et al., 2022).

In PSS design, life cycle cost analysis shifts from minimizing product ownership costs to treating service and maintenance costs as “design variables” that can be balanced against product features and performance to enhance customer value, for example, by offering up-to-date performance or enabling greater focus on the company’s core business.

In PSS, an optimized product design together with adaptable service offerings is essential. In addition, managing product ownership and service-related data over the entire lifecycle is vital for accurately estimating through-life costs and associated benefits (Settanni et al., 2014).

PSS design faces multiple challenges, including extensive customization that can give rise to hidden user requirements, conflicts between design attributes, and complex internal service processes (Song, 2019).

During the SPSS design process, assessing customer satisfaction and pinpointing improvement opportunities during the early product design stage are critical. Moreover, a systematic approach is required to enhance PSS performance in sustainable supply chain management to ensure customer satisfaction (Kuo et al., 2019).

For a successful PSS, designers must balance customer value with economic cost, most of which is determined during the early design stages. Consequently, it is essential to integrate human behavior into design, as interactions and behaviors influence the stochastic elements of services (Kimita et al., 2012).

Table 11. The relationship of PSS cost analysis and PSS design tactic.

Authors, year	Research purpose	Contribution	Application	Theory	CEM
Zhang et al. (2023)	Development of a multi-objective stochastic programming model aimed at maximizing both expected customer satisfaction and sales profit.	T, M	Numerical example	Stochastic theory	PM
Wang et al. (2022)	Exploration of feasible design schemes for Product-Service Systems for Energy Communities (PSS-ECs), including constraints, Life Cycle Cost (LCC) evaluation, and optimization of PSS-ECs design.	T, M, E	Subway bogie and maintenance service	Bayesian network	EA
Fadeyi & Monplaisir (2022)	Integration of LCC into a modular product to enhance PSS remanufacturing product offerings, along with multi-objective analyses to assess optimal product configurations.	M, E	A modular subassembly	Multi-criteria decision-making theory	EA & IM
Rodríguez et al. (2022)	Establishment of a cost estimation framework grounded in a systems-thinking approach, comprising iterative modules and methodological foundations.	M, E	Numerical control machines	System thinking	PM
Chen et al. (2020)	Creation of a criteria system for selecting smart PSS design alternatives, integrating cost and benefit considerations through the rough-fuzzy Data Envelopment Analysis (DEA) method.	M, E	Smart conditioner service system	Rough-fuzzy DEA	NM
Bertoni & Bertoni (2020)	Development of an LCC estimation model based on concept design simulations to explore the feasible design space using Computer-Aided Engineering.	M, E	Turbine rear structure (TRS) of commercial jet engines	NM	PM
Kambanou & Sakao (2020)	Formulation of guidelines based on LCC that fulfill development criteria, illustrated through case studies from three companies.	M, E	3 Suppliers of material and digital visibility, Furniture, &	NM	NM

Authors, year	Research purpose	Contribution	Application	Theory	CEM
			vacuum waste collection systems		
Kambanou (2020a)	Implementation of LCC at a case company to enhance Life Cycle Management (LCM) of their PSS, with additional discussions on practitioners' uses for LCC.	E	Multinational supplier of industrial equipment	NM	NM
Kuo et al. (2019)	Analysis of a leasing model's profit and cost variables compared to a selling model to evaluate a proposed sustainable PSS.	M, E	Heat pump water heater	Regression analysis	PM
Schuh et al. (2019)	Introduction of a feasible method for early assessment of maintenance and service costs during product development.	M, E	Electric vehicle manufacturer	Regression analysis	ABC
Shen et al. (2017)	Establishment of a framework for cost evaluation in PSS configuration.	M, E	A pump PSS	Mass customization	ABC
Schuh et al. (2017)	Development of a model for evaluating variety-induced costs in PSSs, quantifying the cost of a given PSS configuration.	M, E	Machinery	NM	ABC
Bonetti et al. (2016)	Exploration of the application of Total Cost of Ownership (TCO) concept to aluminum melting furnaces.	E	Aluminum melting furnaces	NM	PM
Sakao & Lindahl (2015)	Creation of a method and Excel & MATLAB-based tool supporting Integrated Product-Service Offering (IPSO) design through LCC analysis from provider and customer perspectives.	T, E	Forklift trucks provider	NM	NM
Kimita et al. (2012)	Development of a service cost simulation method considering stochastic service elements to evaluate design solutions from an economic cost viewpoint.	M, E	Elevator operating service	Discrete event simulation	ABC

CEM: Cost Estimation Method, EA= Estimating by analogy, IM= Intuitive method, PM= Parametric method, ABC= Activity-Based Costing, NM=Not mentioned; Type Of Contribution: T=Theoretical, M=Methodological, E=Empirical

- PSS sustainability tactic (refer to Table 12):

The concept of sustainability, at the core of servicizing business models (Arani et al., 2022), drives several business model innovations, including the service shift from products to services, exemplified by product-service systems. When designers, manufacturers, service providers, and other stakeholders collaborate, the service shift has been shown to improve sustainable supply chain performance (Kuo et al., 2019).

Although many PSS studies assert that implementation provides environmental benefits, recent research indicates that, in some cases, PSS business models may negatively impact the environment while still delivering economic benefits (Kuo, 2011). Implementing sustainability strategies by enhancing resource utilization and innovation signals a proactive approach, ensuring that sustainability-driven changes achieve both economic and environmental objectives (Reim et al., 2015).

Researchers have emphasized that PSS stimulates the design of products that are beneficial for the environment (Lindahl et al., 2014). Some PSS studies concluded that the integration of remanufacturing and PSS effectively could mitigate sustainability issues caused by manufactured products (Fadeyi & Monplaisir, 2022).

Table 12. The relationship of PSS cost analysis and PSS sustainability tactic.

Authors	Research purpose	Contribution	Application	Mentioned theory	CEM
Walk et al. (2023)	Development of a guideline to inspire researchers and practitioners, advocating for the integration of computer vision technology in analogous contexts to foster the creation of sustainable smart product-service systems and promote cleaner production.	M	Machining tools	NM	NM
Kambanou (2020b)	Exploration of the implications of implementing Life Cycle Costing (LCC) on Life Cycle Management (LCM) through case studies.	T, E	Industrial equipment manufacturer	Practice theory	NM
Akbar & Hoffmann (2018)	Conceptualization of the consumer's decision-making process regarding a Product-Service System (PSS) sharing offer, grounded in a comprehensive cost-benefit analysis.	M, E	Bike Sharing (as a social media questionnaire)	Regression analysis	NM
Zhang et al. (2018)	Introduction of an evaluation tool that integrates Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methodologies to facilitate the development of PSS for the Healthcare, Education, Commercial, and Entertainment (HECE) sectors.	M, E	High energy-consuming equipment provider	Decision making theory	EA
Lindahl et al. (2014)	Calculation and comparison of the environmental impacts and economic costs associated with different offerings in Integrated Product-Service Offering (IPSO) cases using LCA and LCC methodologies.	E	Paper mills, building cleaning, soil compacting	NM	NM

CEM: Cost Estimation Method, EA= Estimating by analogy, IM= Intuitive method, PM= Parametric method, ABC= Activity-Based Costing, NM=Not mentioned; Type Of Contribution: T=Theoretical, M=Methodological, E=Empirical

Table 13 illustrates the overall relationship between cost analysis and PSS operational tactics in selected publications. PSS cost analysis is most frequently implemented in the "contract" tactic and least frequently in the "sustainability" tactic.

Table 13. Overall relationship of cost analysis and PSS operational tactics.

PSS Business Model Implementation Operational Tactics	No. of Publications
Design	15
Contract	18
Marketing	7
Network	14
Sustainability	5

Figure 4 represents the distribution of reviewed publications across PSS operational tactics. Contract and Design tactics lead in publication frequency (18 and 15 studies respectively), indicating a dominant scholarly focus on legal structuring, pricing models, and product-service integration strategies in PSS. Network tactics are also moderately represented (14 studies), reflecting the importance of stakeholder coordination and external partnerships in delivering value. In contrast, Marketing and Sustainability tactics appear less frequently (7 and 5 studies, respectively), which may suggest under-explored areas. This uneven distribution highlights the need for broader exploration, especially regarding customer engagement strategies and environmental impact within PSS models.

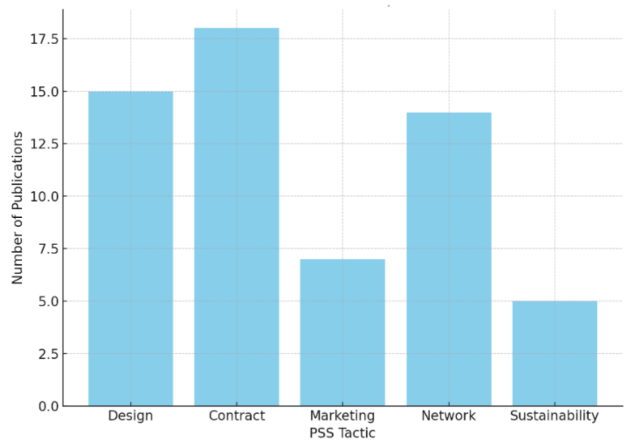

Figure 4. Number of publications per PSS tactic

To further facilitate the understanding of the theoretical foundations underlying the reviewed studies, a conceptual network map was developed (see Figure 5). The network map presents a conceptual landscape of the theories underlying cost and performance analysis in PSS literature. Decision-Making Theory, Uncertainty Theory, and Game Theory appear as central nodes, frequently co-occurring with others like Risk Theory, Pricing Theory, and Utility Theory. This reflects the complex, multi-dimensional nature of PSS decision environments, where cost, value, and performance are interconnected. The clustering of simulation-related theories (e.g., Discrete Event Simulation, Agent-Based Simulation) around uncertainty underscores the role of modeling in navigating unpredictable cost behaviors. The dense interconnectivity suggests a growing trend toward integrated, multi-theoretical approaches in PSS research — combining economic, behavioral, and technical frameworks to capture the full scope of product-service dynamics.

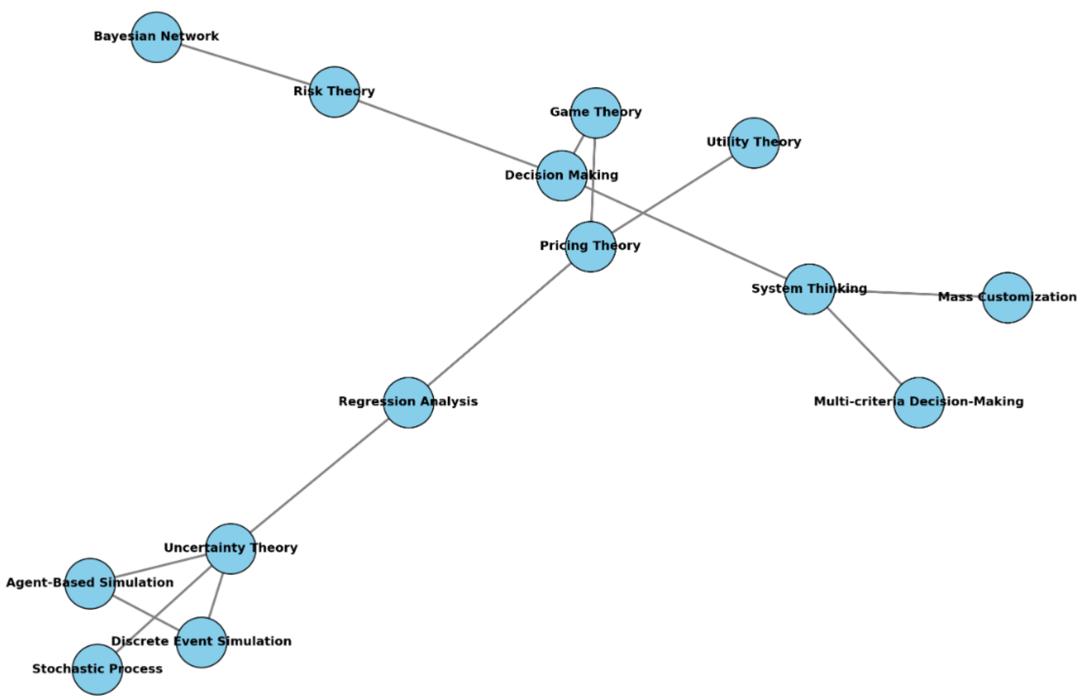

Figure 5. Network map of theories across studies

4.2. PSS Cost Estimation Methods

The method for cost estimation depends on data availability and the specific type of Product-Service System (PSS) being evaluated. No single lifecycle cost analysis method is universally sufficient for evaluating all cost elements (Bertoni & Bertoni, 2020; Estrada & Romero, 2016; Fadeyi & Monplaisir, 2022).

PSS cost estimation methods are classified based on data nature and analysis type into four categories:

- *Qualitative Techniques*

Estimating by Analogy: Analogy-based methods rely on past costs from similar or legacy systems, adjusted for differences between existing and new systems. This method assumes that historical costs are reliable predictors of future costs (Rodríguez et al., 2020; Datta & Roy, 2010). Techniques in this category use similarity criteria based on historical cost data, such as regression analysis models or backpropagation methods (Niazi et al., 2005).

Intuitive Method: Intuitive estimates are based on the expertise of the estimator (Datta & Roy, 2010). Expert knowledge is systematically utilized to generate cost estimates, which may be stored as rules, decision trees, judgments, etc., to aid decision-making (Niazi et al., 2005). Subcategories include case-based methodology and decision support systems.

- *Quantitative Techniques*

Parametric Method: Parametric methods estimate costs based on an analytical function of parameters without fully describing it (Datta & Roy, 2010). Parametric models are derived using statistical methodologies, expressing cost as a function of variables (Niazi et al., 2005). They assume that factors influencing past costs will continue to do so in the future, identifying statistical correlations between past cost data and key program, physical, and performance variables (Rodríguez et al., 2020).

Activity-Based Costing (ABC): ABC calculates costs incurred in performing activities to manufacture a product (Niazi et al., 2005). It is a bottom-up technique where cost data is collected from the smallest component levels and aggregated to the total product level (Datta & Roy, 2010). ABC is used in research to configure PSS and determine the most suitable PSS solution from the standpoint of the manufacturer (Shen et al., 2017). Additionally, ABC considers uncertainty propagation for PSS solutions. Different types of ABC include time-oriented, resource-oriented, or a combination of both (Rodríguez et al., 2020).

Figure 6 illustrates the distribution of cost estimation methods used in the reviewed studies. This pie chart illustrates the prevalence of different cost estimation methods in the selected literature. Parametric methods are the most commonly applied (approximately 41%), reflecting their perceived reliability for quantifying costs based on statistical relationships. Activity-Based Costing (ABC) and Estimating by Analogy also show moderate usage, highlighting the relevance of granular and experience-based approaches in complex service settings. Intuitive methods are least utilized (only ~3%), likely due to their subjectivity. Notably, about 29% of the studies did not specify any cost estimation approach, suggesting a methodological gap and indicating that many studies may lack a formalized cost analysis framework — an area for future improvement in academic rigor.

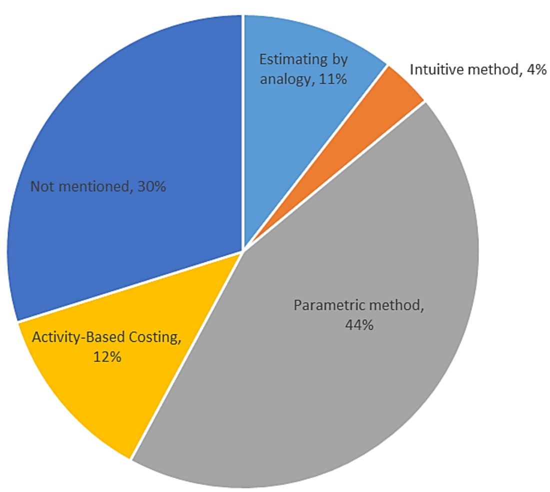

Figure 6. Distribution of cost estimation method in selected publications

4.3. Cost Analysis from PSS Strategies Viewpoint

According to selected publications, cost analysis in PSSs context can be investigated from different viewpoints which are discussed below:

Life Cycle Costing (LCC): It is employed to measure the economic costs of a product throughout its entire lifetime (Schneider et al., 2022). Notably, the absence of LCC in the product development phase within a PSS-remanufacturing integrated framework is a significant limitation since decisions made during this phase account for over 70% of the product lifecycle costs (Fadeyi & Monplaisir, 2022). PSS, viewed through the lens of product life-cycle analysis (LCA), spans phases from development and manufacturing to distribution, usage, and final disposal or recycling. While LCC positively influences life cycle management (LCM), it might narrow the understanding of the term life cycle, potentially neglecting the sustainability aspect of LCM (Kambanou, 2020b). In contrast, Kambanou & Sakao (2020) argue that implementing LCC in PSS can provide information on financial consequences and offer insights into resource efficiency/circularity aspects.

Life cycle assessment (LCA), a popular tool for assessing environmental impacts associated with a product's lifecycle, has been applied to support various decision-making procedures in product life cycle management (Zhang et al., 2018).

Performance-Based Contract (PBC): It constitutes an innovative service-oriented approach for delivering product–service solutions. Designed to enhance customer value and lower operational expenses, PBC also presents challenges, including the presence of difficult-to-quantify "hidden costs" (Datta, 2020). The functional product (FP) concept, a form of performance-based contract, entails delivering a mutually agreed function to the customer at a predetermined price for a defined duration, ensuring the promised level of availability and offering compensation if that commitment is not fulfilled (Kyösti & Reed, 2015).

Total Cost of Ownership (TCO): It serves as a widely recognized cost modeling approach within the field of supply chain management that supports the development of PSSs through TCO-based contracts (Roda et al., 2020). Widely adopted in business-to-business contexts, TCO, adopting a lifecycle perspective, supports the analysis of PSSs by enabling a "whole cost" evaluation, leading to eco-efficient choices by customers (Bonetti et al., 2016; Saccani et al., 2017). Unlike LCC, which adopts the product perspective, TCO considers the buyer's perspective by estimating all costs associated with searching, acquiring, installing, operating, and disposing of a product, typically over a timeframe shorter than its full lifecycle (Saccani et al., 2017).

TCO models may follow a dollar-based approach, including only monetary costs, or a value-based approach, which includes non-monetary costs expressed in monetary terms (Saccani et al., 2017).

Through-Life Costing (TLC): It plays a central role in addressing the cost of servicing durable products. The traditional TLC approach lacks the methodological basis for accurately estimating PSS costs (Settanni et al., 2014). Considering the full lifetime ownership of products and services is essential for comprehensive through-life cost and benefit analysis. Estimating the cost of a PSS should encompass not only the in-service phase of a durable product but also account for the costs of providing advanced services via a socio-technical system (Settanni et al., 2014).

The increased level of service enhances customer value while reducing through-life costs, transferring the responsibility for managing and resolving obsolescence issues away from the customer (Romero Rojo et al., 2011).

Sharing Economy: The sharing economy has grown rapidly in recent years, driven by the global economic downturn and society's attention to sustainable resource usage (Z. Liu et al., 2021). In response, firms from traditional industries have provided sharing services alongside selling products. Challenges arise in profit-making due to heavy asset investment, leading companies to carefully analyze the cost input of participating in the sharing economy (Z. Liu et al., 2021).

Pricing: A pricing system addressing inherent risks and uncertainties of PSS solutions requires the application of costing tools such as considering life cycle costs and integrating usage data (Guzzo et al., 2022). Servicizing, a new business model that integrates services with products, offers various pricing plans such as pay-per-use or pay-per-period schemes, impacting customer usage behavior (Arani et al., 2022). When making pricing decisions in PSS, understanding the uncertainty in cost estimates and other uncertainties influencing bidding success and service contract fulfilment is crucial (Rodríguez et al., 2022).

Pricing contracts can be based on the perceived value of the service contract, known as value-based pricing. This concept of "value co-creation" shifts the view from being a ‘producer’ to a collaborative process, where value is co-created with the customer in the service provision process (Seiringer & Bauer, 2016).

Maintenance: Product maintenance is central to the business model of manufacturing firms transitioning from selling standalone products to offering product-service bundles (Deprez et al., 2021). Cost-based pricing methods, grounded in anticipated maintenance and repair costs, can be adjusted to include targeted risk and profit margins. In PSS, trends consider extending typical maintenance contracts to jointly offer products and services (Jackson & Pascual, 2021). Sustainable product development requires continuous determination and control of maintenance service costs (Schuh et al., 2019). Uncertainty in PSS maintenance cost estimates may be based on different assumptions such as spare parts prices and inflation rates in financial markets (Kreye et al., 2014).

Use-Oriented Product Service Systems, where customers pay for a service without owning the product, rely on modern sensor and wireless communication technologies for condition-based maintenance services (Liu et al., 2019). New technologies like prognostics and health management support maintenance in servitization business models, particularly in aerospace and defence industries (Greenough & Grubic, 2011).

By studying selected papers, it’s apparent that service involves some degree of value co-creation. Service maintenance contract design has been applied in various fields such as equipment repair, aircraft maintenance, and mobile phone sales channels. In PSS, as manufacturers take multiple roles in the supply chain, they can improve the product’s value through the extension of service.

Configuration: In PSS configuration, firms need to collaboratively select modules and set corresponding prices to enhance both sales profit and customer satisfaction (Zhang et al., 2021). Configuration systems are increasingly used to efficiently design customized PSS to meet demanding customer needs, making cost evaluation crucial in decision-making for configuration selection (Shen et al., 2017). Different product-service configurations are effectively offered by the product portfolio of a company, with each alternative PSS containing a specific product-service configuration by combining product and service features attributes (FA) (Schuh et al., 2017). In PSS, when customer requirements change significantly, PSS providers may need to rearrange service processes and resources or even redesign the entire PSS, potentially causing an increase in service response time and cost (Song,

The utilization of exchangeability in integrated product-service offerings design is a novel approach, previously unattainable when the design parameters were focused on either physical products or service activities. This unique opportunity has emerged through PSS design, allowing the selection of a more cost-effective option to generate value, irrespective of whether the target improvement is a product or service (Sakao & Lindahl, 2015).

In the context of fulfilling increasing customer value, a fundamental concept in PSS, the customer domain is characterized by a set of customer values that represent market segmentation demands for PSS. These values trigger downstream design mappings in a cascading manner. The key challenge is to initiate the design process from the perspective of unique customer values. These identified values should be regarded primarily as requirements for the desired function. Accordingly, customer values are first translated into functional requirements within the function domain. The linkage between the customer and function domains represents the front-end challenges of order configuration. Therefore, one of the primary cost objects in PSS configuration solutions is a timeframe during which purposeful actions are interrelated, contributing to the creation, sustenance, or disposal of a PSS, ultimately producing value for customers (Shen et al., 2017).

Uncertainty: The complexity of PSS behavior is a key factor contributing to a lack of "cost consciousness" (Estrada et al., 2017; Kreye et al., 2014). By conceptualizing PSS as a complex system, its main features include dynamic PSS operation behavior, interaction among multiple interconnected cost objects simultaneously, cost as a vital attribute of PSS operation, and the emergence of patterns between OEMs and customer activities (Rodríguez et al., 2020; Kreye et al., 2014; Settanni et al., 2014; Erkoyuncu et al., 2011).

Various elements contribute to the unpredictability of PSS costs, including the heterogeneity of PSS components, inconsistency in service quality, incentive or penalty mechanisms, the long-term nature of contracts, the complexity of PSS design and customer incorporation, uncertainty of PSS requirements and their variability, products and support services as an integrated offering, changes in the ownership mechanism, value co-creation, and unclear boundaries between organizational activities (Rodríguez et al., 2020; Shen et al., 2017; Sakao & Lindahl, 2015; Erkoyuncu et al., 2011).

Uncertainty, defined as the vagueness of the outcomes in each situation (Erkoyuncu et al., 2011), is intensified through the complexity of the PSS cost estimation process. This is largely due to the increased complexity and unpredictability in costs associated with delivered services (Shen et al., 2017; Erkoyuncu et al., 2013). Firms encounter significant uncertainty due to the long-term nature of services (Kreye et al., 2014), and life cycle uncertainty further exacerbates the complexity of PSS cost estimation (Erkoyuncu et al., 2013).

The maximum net value of PSS complexity can be calculated as the difference between its value and the costs associated with variety, highlighting that variety-related costs must be accounted for when defining a specific product-service system (Schuh et al., 2017).

Figure 7 illustrates the conceptual relationships between key PSS implementation tactics and strategic cost analysis viewpoints. Each link represents a conceptual or thematic connection drawn from reviewed literature, highlighting the interdisciplinary nature of cost considerations in Product-Service Systems.

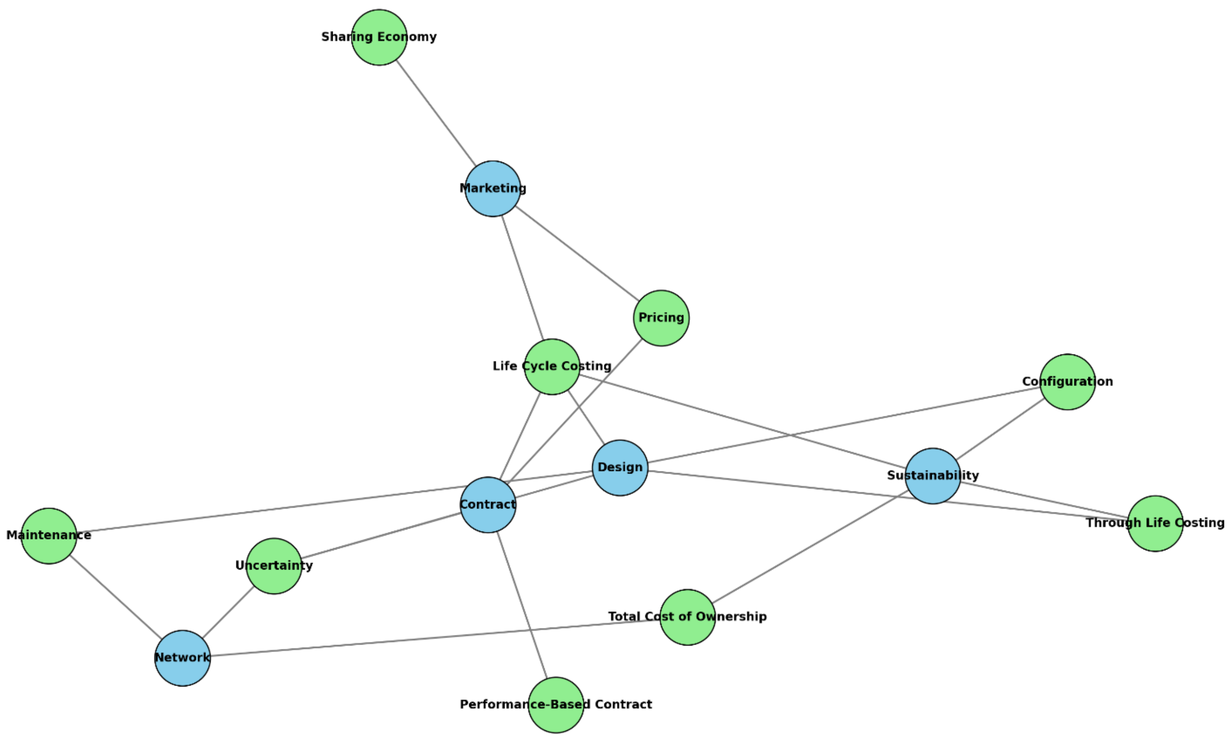

Figure 7. Conceptual mapping between PSS tactics and strategic cost viewpoints

The design tactic shows the widest range of connections, spanning across life cycle costing, configuration, maintenance, through-life costing, and uncertainty. This breadth reflects the critical role of early design decisions in shaping the total economic and functional outcomes of PSS offerings. Since design decisions largely determine lifecycle and through-life costs (Settanni et al., 2014), this connection is expected. The strong tie with uncertainty also reinforces the literature’s acknowledgment of design-phase complexity, especially in balancing customization with cost predictability.

The contract tactic is strongly linked to performance-based contracting, pricing, uncertainty, and life cycle costing. These connections emphasize the importance of cost control and risk-sharing mechanisms in contractual PSS structures. Performance-based contracts, in particular, shift financial risk to providers, requiring robust life cycle cost forecasting and compensation schemes that address service-level uncertainties. The presence of both pricing and uncertainty points to the need for multi-criteria optimization during the contract negotiation and bidding stages (e.g., Jackson & Pascual, 2021; Erkoyuncu et al., 2011).

The marketing tactic exhibits fewer but focused connections, particularly with the sharing economy, pricing, and life cycle costing. This limited scope may reflect an academic underrepresentation of market-facing strategies in PSS, despite their real-world importance. Nevertheless, these links underscore the centrality of value communication, customer utility, and alternative pricing models (e.g., pay-per-use) in market-oriented PSS strategies. The link to the sharing economy shows alignment with current trends in sustainable consumption models (Z. Liu et al., 2021).

The sustainability tactic connects prominently to life cycle costing, total cost of ownership, through-life costing, and configuration. This clustering reflects sustainability’s close alignment with long-term economic and environmental optimization, especially in balancing ownership cost with product reuse and service integration (Fadeyi & Monplaisir, 2022). The connection to configuration also highlights the role of design modularity and remanufacturing in enabling circular economy strategies within PSS.

The network tactic connects mainly with maintenance, total cost of ownership, and uncertainty. These links illustrate how network design, including supplier relationships and service partnerships, significantly influences operational costs and risk exposure. Maintenance, in particular, emerges as a key node, underlining the importance of logistics and service reliability within distributed PSS delivery systems (Deprez et al., 2021).

5. Conclusions

One of the hurdles to PSS development is its business model, and assessing its feasibility necessitates addressing cost analysis. Despite recent emphasis on the value creation of PSS, cost analysis remains essential as a justification indicator for a PSS business model.

Intangible value has become pivotal in gaining competitive advantages and outperforming competitors. Moreover, this intangible added value makes clients willing to pay more than rationality would dictate. Consequently, the basis of competition has shifted from a single product to a customized solution, comprising tangible products and intangible services designed and combined to meet specific customer needs economically and sustainably. The concept of 'value co-creation' shifts the perspective from being a 'producer' to a collaborative process, where value is co-created with the customer in the service provision process. This argumentation applies to the PSS lifecycle, where provider and customer interaction are crucial (Seiringer & Bauer, 2016).

The co-creation of value is a concept that has gained popularity, fostering collaboration between the customer and the industry to meet service requirements. For example, data regarding product performance and usage are shared with the industry, supporting the enhancement of performance parameters (e.g., maintenance schedules). However, value co-creation in PSS particularly hinges on customer affordability and supplier profitability. To measure these metrics, understanding the uncertainty in cost estimation is crucial for making rigorous decisions at the bid stage (Erkoyuncu et al., 2011). Customers realize their value-creating potential through gaining experience in managing service support contracts (Datta, 2020).

Traditionally, three main pricing strategies are distinguished in the literature on marketing and management accounting: cost-based, competition-based, and value-based pricing. Through cost-based pricing, a company determines the price based on cost plus a desired profit margin, while in competition-based approaches, market pressures also influence prices, varying based on competitors' behavior. In value-based pricing, prices align with the value created for customers. Although cost-based pricing is considered ineffective in a service-oriented business, in PSS businesses where both products and services are integrated, focusing on cost in pricing strategies is inevitable. Existing research and the typology of services (especially digital ones) are not extensive enough to construct a pricing model based on value-in-use. Instead, a cost-based pricing logic is more commonly adopted to create a general model to contribute quantitatively to the decision-making of PSS providers.

By examining research relevant to the scope of this paper, the primary areas for future research are outlined as follows:

- Value-Based Pricing using Utility Theory:

  Incorporating customer value as a quantifiable metric poses a significant challenge in PSS cost analysis. The utility theory emerges as a valuable tool for capturing customer preferences, enabling the implementation of a PSS pricing mechanism that interprets both value and cost into measurable and comparable quantities.

- Calculation of Eco-Cost Value (A Life cycle assessment indicator for sustainability assessment):

Assessing sustainability as a key driver in PSS is a formidable task. The calculation of Eco-Cost value offers a solution for PSS developers to address this challenge. The Eco-Costs/Value Ratio (EVR) serves as an indicator of the environmental impact of purchased products, with value representing the price paid in a free-market economy.

- Utilizing Simulation Models for Uncertainty Management:

  Simulation methods, particularly Agent-Based Simulation (ABS), play a crucial role in managing uncertainty within PSS cost analysis. The increased adoption of hybrid simulation methods, integrating system dynamics, agent-based modeling, and discrete event simulation, proves beneficial in addressing heterogeneity within PSS cost elements. This approach can enhance the understanding and management of uncertainties associated with PSS cost analysis.

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