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# A CRITICAL REVIEW OF PRODUCT SERVICE SYSTEM RISK MANAGEMENT: BIBLIOMETRIC ANALYSIS AND NEW RESEARCH DIRECTIONS

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**Abstract.** *In order to fulfil users' needs in a highly competitive business environment, providing Product Service System (PSS) is a valuable opportunity for manufacturing companies to achieve sustained profitability. PSSs are exposed to risks of different natures at a significantly higher level for both companies and clients. Managing the risks in the development or in the operation of a PSS can contribute with greater probability of reaching the business objectives and encourage a proactive management in the company. Within this context, this article aims to present a bibliometric and content review analysis of the main contributions of the literature on the subject of PSS risk management, in the last 10 years. After a review of the mainly publications from 2010 to 2020, this study systematically presents a review and critical reflection on the current status of PSS risk management and research gaps and future agenda. This paper concludes that most PSS risk management studies address customer's perceived risks and risk management framework. Finally, this paper may serve the academic point of view as a guide for the development of new research on PSS risk management, as well as a basis and incentive for the practice of risk management in real projects.*

**Keywords:** *product service system; risk management, bibliometric analysis.*

## 1. Introduction

The first use of the term servitization was by Vandermerwe and Rada (1988). They defined servitization as “the increased offering of fuller market packages or ‘bundles’ of customer focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings”. Here, the authors took the view that “services are performed and not produced and are essentially intangible”.

There are other definitions of servitization in the wider literature. Servitization is the transformation of a firm from taking a product-to-taking a service-centric approach. It represents a significant change in the business model and mission of the firm, whereby the service business serves as a growth engine of the firm (Kowalkowski et al. 2017).

The rapid expansion of servitization has given rise to the term "Product-Service Systems" (PSSs) which has been defined as “a marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfillment or economic value” (Goedkoop et al. 1999). Thus, a PSS should be defined as a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models (Mont, 2002).

In the context of PSS, providers are exposed to new types of risks at a significantly higher level, which are not fully understood. However, detailed insights into different PSS-related risks continue to be a limited and largely neglected area of research (Erkoyuncu et al. 2011). From the manufacturers point of view, PSSs are subject to risks as financial risks linked to the customization bundling; risk of overdesigning de PSS and not fulfill the users' needs; and environment-related risk, this encompasses all the types of risks that affect the external environment where both the customer and supplier operate. To the consumers, the following risks may occur: Dependence on supplier after purchasing a PSS; the perceived risk, that is, the risk that the customer perceives to be associated with the value realization process; and use-related risk: unsatisfying product outputs

Risk is the effect of uncertainty on objectives. An effect is a deviation from the expected - positive and / or negative. Objectives can have different aspects (e.g. financial, timescale, health, safety or environmental) and can apply at different levels (such as strategic, organization-wide, project, product and process). Risk is often expressed in terms of a combination of the consequences of an event and the likelihood of associated occurrence (IEC 31010:2019). In this sense, risks are differentiated clearly from uncertainty, which is not possible to predict and calculate in advance (Knight 1921).

So, it is critical to identify, analyze, treatment, monitor and control the risks, that is, manage the risks involved in order to help companies make appropriate decisions; as these decisions have a large impact on the Product Service Life Cycle. Risk management techniques aim to help people understand uncertainty and the associated risk in this broad, complex and diverse context, for the purpose of supporting better-informed decisions and actions (IEC 31010:2019).

For managers, responsible for developing and operating PSS offerings, it is especially important to realize that risk management is a vital activity that extends beyond technical risks that lead to breakdowns of the product to also include risks related to customer behavior and insufficient competence at the providers' end (e.g. service delivery network) (Reim et al. 2016).

The purpose of this article is a study and critical review of the scientific literature produced by the main researches in the last 10 years about the Product Service System Risk Management. The structure of the paper is organized as follows. Section 2 deals with the research methodology. Section 3 describes the results of the bibliometric analysis. Section 4 presents a systemic analysis of the articles listed as most relevant for understanding the topic. Finally, the article ends with the discussions and conclusions about the current status of PSS risk management and future agenda in this area.

## 2. Research Methodology

In order to conduct a bibliometric review on PSS risk management, a quantitative and qualitative research method denominated the Theory of the Consolidated Meta-analytic Approach (TEMAC) was adopted. The main steps of the method used were: (1) preparing the research, (2) presenting and inter-relating data, (3) detailing the integrating model and evidence-based validation (Mariano et al. 2019).

The first step includes the definition of: the database to be consulted, keywords, type of documents, timeframe and knowledge areas within which the review will be investigated. In the second step, bibliometric information is extracted from the literature databases such as: number of publications, document types, countries with more publications, keywords clustering and top 10 articles that have been historically most cited in the period of 2010 – December 2020.

Finally, the third step of the TEMAC method is to analyze the main contributions present in the consolidated basis, by means of co-citation and coupling/mapping study. This study used the 1.6.5 version of the VOSviewer software to ensure a satisfactory analysis of the bibliometric data. The three-step workflow of the bibliometric review in this study is illustrated in Figure 1.

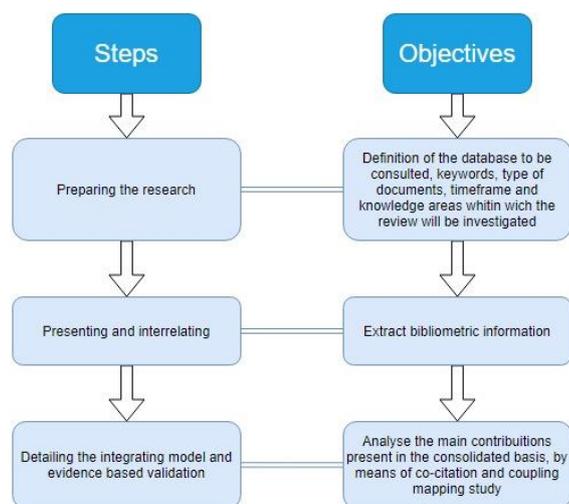


Figure 1. Steps of the PSS Risk Management bibliometric analysis.

## 3. Results and Analysis

### 3.1. Preparing the Research

First, the electronic database of Web of Science (WoS) was chosen as a search engine because it is the most widely accepted and frequently used database for analysis of scientific publications (Yang, Rana and Evans 2013). Publications were searched in the databases by combining the following keywords and their variations: (i) “product service system\*” and risk\*, (ii) “product service system\*” and “risk management\*”, and (iii) “product service system\*” and uncertainty\* and risk\*. These keywords were selected because they are the basis of the risk management theme as showed in section 1.

Second, filters were applied on this research to include articles and proceedings papers; from 2010 until June 2020. Then, the filtered search resulted in 78 articles in the WoS database. Finally, we applied one more filter considering the

following knowledge areas: industrial engineering, manufacturing engineering, management, mechanical engineering, operations research and management science and engineering multidisciplinary which resulted in 56 articles. After that, 35 was selected to be analyzed based on the title, abstract and keywords. For this selection, articles with the following terms were considered: product service system, uncertainty and risk in the title, abstract ou keywords. After, based on the objective of the present research, 24 articles were selected for the complete reading. All research was carried out from August 01th, 2019 to January 4th, 2021.

### 3.2 Data presentation and interrelations

The number of peer-reviewed publications is an important indicator to measure the development trend of a scientific research subject. As displayed in Figure. 3 (letter a), the number of PSS Risk Management publications started in 2011, with only three publications. In the years of 2012 and 2013 there were 4 publications, in each year. In 2014, 2015, 2016 2018 an increasing number of publications arose. A publications peak was reached in 2017, with 11 publications. After this period, a declining trend occurred in 2018 with 3 publications and in 2019 with 2 publications. The year 2020 has three articles published until June.

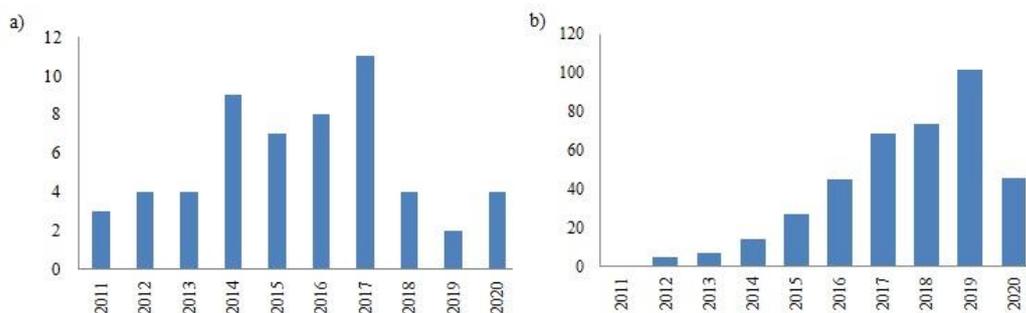


Figure 2. a) Evolution of the number of publications. b) Evolution of the number of citations on the PSS Risk Management theme. Source: (Web of Science 2020).

In regard to the evolution of citations over time, Fig. 2 (letter b) shows that the PSS Risk Management theme has its use increased in the scientific community from 2012 until 2019. From Figure 3, one may infer that the study of PSS risk management is something recent, limited, and with potential to be developed.

Most of the 56 publications provided by the database search (2010-2020) are proceedings papers (53,85%), followed by journal articles (47,44 %). Considering the 56 publications, 87,5% are classified in the Engineering research area and 9,78% in Operations Research Management Science. The others are classified in several areas as Business Economics and Computer Science. It indicates that although risk management in PSS can be used in many areas, the most common application of theme is related to engineering.

Table 1 lists the top 10 cited publications according to the WoS citation metric, such as the total number of citations, article title, author, journal or proceedings paper and year (Web of Science 2020). One can observe that the most highly cited article is entitled “Risk management for product – service system operation” published in the International Journal of Operations & Production Management in 2016, with 34 citations. The objective of the publication was to present a risk management structure and decision criteria that influence the choice of risk response (Reim et al. 2016). A large number of the articles, listed in Table 1, show the use of framework for the PSS Risk Management, or proposed the study of uncertainties and risks in the PSS.

Table 1. Top 10 cited articles in 2010-2020 (Web of Science 2020).

Citations	Article	Author	Journal or Proceedings Paper	Year
34	Risk management for product-service system operation	Reim, et al.	International Journal of Operations & Production Management	2016
31	RFID-enabled product-service system for automotive part and accessory manufacturing alliances	Huang, et al.	International Journal Production Research	2012
27	Devising hybrid solutions: an exploratory framework	Rapaccini, et al.	Production Planning & Control	2015
25	RFID-enabled gateway product service system for collaborative manufacturing alliances	Huang, et al.	CIRP Annals - Manufacturing Technology	2011
24	Uncovering benefits and risks of integrated product service offerings - Using a case of technology	Sakao, et al.	Journal of Systems Science and Systems Engineering	2013
22	Strategic framework for industrial product-service co-design: findings from the microsystems industry	Durugbo	International Journal of Production Research	2014
22	Uncertainty in competitive bidding - a framework for product-service systems	Kreye, et al.	Production Planning & Control	2014
20	Network positioning and risk perception in servitization: evidence from the UK road transport industry	Bigdeli, et al.	International Journal of Production Research	2018
16	A chance discovery-based approach for new product-service system (PSS) concepts	Park, et al.	Service Business	2015
15	PSS modularisation: a customer-driven integrated approach	Fargnoli, et al.	International Journal of Production Research	2019

The bibliometric analysis also revealed that the largest number of publications over the last decade were conducted in the UK (13%), closely followed by Germany (12%) and Italy (7%) in third place.

### 3.3 Detailing, integrative model and evidence validation

Here we show the third step of the TEMAC method, when the co-citation analysis is performed. This analysis focuses on the relationship or interaction between two publications, and gives an overview of publications that have been cited together in other publications. The more two publications are cited together, the more similarities between them can be assumed. That is useful to identify authors who follow similar lines of research.

The result of the co-citation analysis is presented in Figure 3. The size of the circles represents the number of citations, i.e. the larger a circle, the more a publication has been cited. VOSviewer (2020) was used to analyze and visualize the co-citations.

A smaller distance between two publications indicates a stronger relation and a higher similarity between them. Circles with the same color suggest similar information among these publications. The co-citation map in Figure 3 shows two different clusters, where each cluster represents a field of PSS Risk Management research.

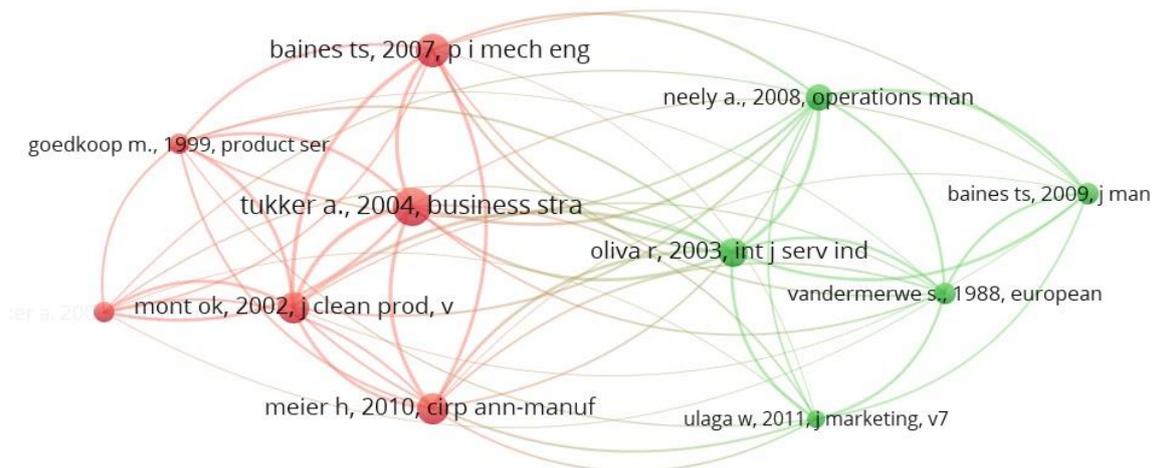


Figure 3. Co-citation density map (VOSviewer (2020); Web of Science 2020).

The red cluster is led by Tukker (2004) says that at least eight different types of PSS exist, with quite diverging economic and environmental characteristics. The economic potential of each type was evaluated in terms of (i) tangible and intangible value for the user, (ii) tangible costs and risk premium for the provider, (iii) capital/investment needs and (iv) issues such as the providers' position in the value chain and client relations. The environmental potential was

evaluated by checking the relevance of certain impact reduction mechanisms (e.g. more intensive use of capital goods, inherent incentives for sustainable user and provider behaviour etc.). Approaches should be developed that can reduce the liability risks and enhance control over 'production' uncertainties related to functional PSSs (Tukker, 2004).

Then, the state-of-the-art of PSS research was reported, by presenting a critical review of literature currently available on this topic. The literature is then classified and the major outcomes of each study are addressed and analyzed. The paper defines the PSS concept, reports on its origin and features, gives examples of applications, along with potential benefits and barriers to PSS adoption, summarizes available tools and methodologies, and identifies future research challenges (Baines et al. 2007).

In turn, a theoretical framework for PSS was proposed and serves as a background for identifying possible investment needs in studying them. There are three main uncertainties regarding the applicability and feasibility of PSSs: the readiness of companies to adopt them, the readiness of consumers to accept them, and their environmental implications. The main finding is that successful PSSs will require different societal infrastructure, human structures and organizational layouts in order to function in a sustainable manner (Mont, 2002).

Meier, Roy and Seliger (2010) shows the influences of business models on uncertainty and risks sharing between the customers and OEMs (Original Equipment Manufacturers). Customers' proportion on uncertainty and risks share is higher in the function-oriented business model, whereas OEMs responsibility on uncertainty and risks is higher in the result – oriented business models.

A method to analyse the economic and ecological qualities of Product Service systems was proposed. They believe an understanding of product service systems is a next step on the way to *ecology*: the junction of ecology road and economy lane. The paper gives basic observations and definitions, offers an outline of a new assessment method and ten case descriptions. The risk types that may exist in PSSs projects were also identified (Goedkoop et al, 1999).

Finally, in the green cluster, the most cited article is Oliva and Kallenberg (2003) which reported the findings from a qualitative field study of 11 capital equipment manufacturers known to have initiated an explicit service strategy to support their products. About risk management, pricing equipment availability requires the service provider to assume the equipment's operating risk, i.e. pricing will be based either on the opportunity cost of machine failure, or the traditional maintenance cost for the end-user's maintenance organization. Profitability under this pricing mechanism depends on how accurate the organization is in assessing the failure risks for the equipment.

Besides that, a coupling analysis was performed (Figure 4), which revealed the main research fronts of the last three years, that is, how the studies were configured in this period. The coupling maps shows how an author relates to others based on articles that cite similar works. The circles and lines of the same color indicate that the articles are addressing a common theme by citing other articles in common. A smaller distance between two publications indicates a stronger relation in terms of citing other articles in common.

According to Figure 4, the four largest circles represent the four authors that stand out in this period. Ziaee Bigdeli et al. (2017) focused on understanding managers' risk perception of servitization implications for strategic partnerships and network positioning, while considering the impact of factors such as entry barriers, technological knowledge and position in the supply chain (SC). Qualitative evidence was drawn from an industrial case study involving firms in the UK's road transport industry. Results suggested that implementing advanced services is perceived as a high-risk strategy, especially when firms lack in-house technological knowledge. However, collaborative strategic partnerships within supply chain networks can mitigate risks and prove crucial to building entry barriers against external competitors.

A practical methodology to support manufacturers in designing services related to the proper functioning of their products fulfilling customers' needs and expectations was proposed. The approach was based on the synergic use of Quality Function Deployment for PSS (QFDforPSS), Axiomatic Design (AD) and the service blueprint tools, providing a correlation between the customers' expectations, the PSS components and the PSS modules (Fargnoli, Haber and Sakao, 2018).

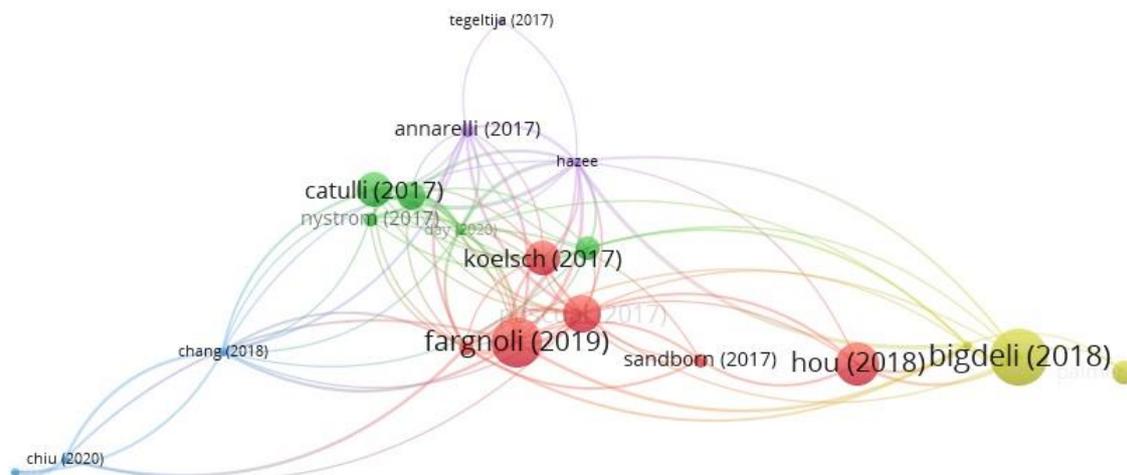


Figure 4. Bibliographic coupling density map. Source Web of Science. Map generated by VOSViewer Version 1.6.12.

Baines (2009) conducted 24 interviews with 11 companies to explore risks and risk factors in Outcome-based contracts (OBCs) from the provider's perspective. The case studies revealed that the two major risk categories in OBCs are commercial risk regarding the contract negotiations and contract decisions at the contracting stage, and operational risk regarding the implementation and the delivery of OBCs. The study identified 23 risk factors that can lead to commercial risk and operational risk in five dimensions: (i) complexity and (ii) dynamism regarding the context of OBCs, (iii) capability, (iv) alignment and (v) dependency regarding the stakeholders of OBCs (Baines 2009).

Less related to the theme of PSS risk management and with less citation number, there are references Catulli and Reed (2017) and Kölsch et al. (2017). The first presented a novel concept to develop availability-oriented business models, which considers requirement elicitation for technical development of smart machine components, and customer-oriented methods of design thinking approach, i.e. Persona analysis, Value-network mapping and Customer Journey.

The second explored how consumers construe a PSS for the supply of pushchairs. A PSS is a system of products, services, networks of actors and supporting infrastructure designed to be more sustainable than traditional business models. PSSs face an implementation challenge in consumer markets, and this case-based research explores some reasons for this.

#### 4. Systemic Analysis of Articles

In order to identify research gaps and future agenda, this paper shows a qualitative analysis of the 24 articles. The articles whose themes most closely match the proposal of the present research were selected.

Erkoyuncu et al. (2011) combined service concepts and uncertainty in cost estimation to propose the components of a service delivery system, classification of sources of uncertainty, based on supply and demand, and the suitable uncertainty modeling methods for service cost estimation.

In turn, a conceptual framework that aimed at supporting companies that offer services in making their pricing decision under uncertainty in a competitive bidding situation was proposed. The framework displays the influencing uncertainties on the bidding strategy and pricing decision. These uncertainties were summarised in four factors, namely the service contract conditions, internal company processes, customer and competitors (Kreye, Newnes and Goh 2012).

A Cost Engineering Method for PSS based on a System Cost Uncertainty Analysis (SCUA) was introduced which is a probabilistic method focused on determining the total operational cost of a PSS. The main purpose of this paper is to introduce a PSS cost engineering approach to reduce the aleatory uncertainty that exists in every PSS cost determination, and therefore to provide certainty in the cost-capacity relationship that exists in every PSS offering (Estrada and Romero 2016).

Seiringer and Bauer (2016) presented and evaluated a risk-based costing approach for PSS. Compared to other service costing approaches the costing approach also includes the customer domain. This is done by considering the customer's impact on service production. Consequently, the approach is based on the origin of the costs, and the customer's performance. The service costing approaches of Time-Driven Activity-Based Costing (TDABC) provides a profound base from the provider's point of view.

A customer-based insights into service delivery system design and risk management for sharing-based PSS operational success was provided. First, an integrative conceptual framework that reveals what structural and infrastructural design choices customer expect organizations to make for mitigating risks and enhancing customer-perceived value in the sharing economy was developed. These design choices may influence customers' trust and control perceptions in all actors involved in the service delivery system. Second, the results suggested that sharing value proposition, customer-perceived

level of consequentiality and level of customer-supplied resources are contingency factors that need to be considered when making design decisions for risk management in the sharing economy (Hazée 2020).

Hou and Neely (2017) explored risks associated with Outcome-based contracts (OBCs) from a provider's perspective in the context of servitisation. To supplement the current research on risks of OBCs, it was conducted 24 case studies with servitising firms which adopt OBCs to deliver total solutions, and identified 23 risk factors in OBCs. These 23 risk factors were categorised into two major risk categories in OBCs: (i) commercial risk regarding the contract negotiations and contract decisions at the contracting stage, and (ii) operational risk regarding the implementation and the delivery of OBCs. Also, the 23 risk factors were categorised into five dimensions, which are: (i) complexity, (ii) dynamism, (iii) capability, (iv) alignment and (v) dependency.

A quantitative methodology for the design of use-oriented PSS contracts based on non-repairable component reliability and risk sharing was developed. It can be extended to other performance metrics such as availability and reliability. The objective was that the client and the supplier follow a simple and straightforward formulation to reach an optimal configuration for the contract, based on the extended life sharing factor and the maintenance cost that the client pays. The methodology was tested using a case study that analyses mining haul truck tires (Pascual et al. 2017).

Reim et al. 2016 based on an exploratory study involving a Swedish company, presented a risk management structure and decision criteria that influence the choice of risk response. To achieve that, these authors used a qualitative research approach, based on structured and open interviews to explore which risks were perceived by respondents as most important in the PSS operation, as well as to identify possible risk management strategies to capture possible risk responses.

The objective of Sakao, Öhrwall Rönnbäck and Ölundh Sandström (2013) was to uncover benefits and risks of Integrated Product Service Offering (IPSO) in a systematic manner. First the article proposed a theoretical and generic framework termed the PCP (Provider – Customer – Product) triangle with associated information flow and uncertainty. Second, various types of benefits and risks are presented based on the framework.

Herzog et al. (2014) contributed to the systematic consideration and association of uncertainty and risk management in IPS2 businesses and proposes a new and holistic approach for integrating the concept into the early design phase. Due to the fact that the positive effects of uncertainties are addressed additionally in an explicit way, the traditional understanding of risk management has to be expanded to the management of uncertainties.

A method to the simulation-Based Risk Management of Product-Service Systems was proposed. The simulation was divided in two main parts: modeling and analysis. In the modeling part, a Conjoint System Model (CSM) was developed. The CSM is capable of uniting the modeling world of Petri nets – i.e. a state-space oriented model, the ECSPN – with the RBD –i.e. a combinatorial model. In the analysis part, the Monte Carlo simulation was the used technique for the simulation of reliability and maintenance. The analysis part was based on important parameters which were associated with the product operation and the accomplishment of services as reliability parameters, lifetime distributions and functional parameters (Zeiler and Bertsche 2014).

A reference ontology named FLEXINET to support the decision making processes often found at the early stages of product service development was defined (Kimita, Sakao and Shimomura 2017). Its main aim is to support interoperability between systems and domains, by way of the intelligent configuration of a network of PSS for Global Production Networks (GPN). The research defines a reference ontology that can support risk assessment for GPN in an interoperable manner. The knowledge classifications that follows from the FLEXINET investigation. The main elements of the FLEXINET reference ontology are risk, production network, scenario, location, indicators and metrics, with concepts across these areas being shared with multiple other decision support applications.

More recently, a failure analysis by using the Failure Mode and Effect Analysis (FMEA) tool in the PSS project in order to analyze faults and statistics in the conceptual design phase of the PSS was performed. The procedure for defining a PSS FMEA, consisting of five steps, can be seen in Figure 11 (Kimita et al. 2016).

The target scope of failure analysis from the user requirements point of view is defined in order to provide a PSS that meets them through a description of a flow model. From the model, designers determine the product components and service actors that perform the necessary functions. Shortly thereafter the failure modes are first detected, according to the components behavior and the activities of the previously identified actors while performing the necessary functions, whose product causes of failure, which are then analyzed from the point of view of product and product aspects. services. A calculation involving the product of probability, severity and detection defines the priority in which the failure modes in the PSS project should be addressed. Finally, measures against each failure mode are developed in order to improve the quality and efficiency in performing the required functions of a PSS. The proposed method (PSS FMEA) fulfilled its function of assisting designers in identifying business opportunities.

A methodological framework, including the construction for co-implementation of smart PSS, the formulation for extended-FMECA sheet and the hybrid approach to classify failure modes was proposed. This methodological framework is composed of constructing PCN diagrams for the service process of co-implementation of smart PSS, formulating an extended- FMECA sheet by adding risk factors of adaptation on autonomy means and classifying the failure modes on risk factors into ordinal classes (Liu and Ming 2019).

Finally, Tegeltija, Oehmen and Kozin (2017) presented the challenges of the PSSs risk management through a case study on a large-scale energy company in Denmark. The following challenges were identified in the current risk

management practices that are in line with literature: (1) current methods are not appropriate for the situations dominated by weak knowledge and information; (2) quality of traditional models in such situations is open to debate; (3) quality of input data and representation of the results to the decision makers play an important role.

Risk perception is one of the subject more explored in the risk management PSS literature (Gesing et al. 2014; Maiwald, Wieseke and Everhartz 2014; Rapaccini and Visintin 2014; Ziaee Bigdeli, Bustinza, Vendrell-Herrero and Baines 2017; Durugbo and Wang 2014; Hazée 2020). Customer’s perceived risks, aspects that increase the risk perception, risk reduction strategies, risks perception associated with the supply chain are approached systematically.

The articles that propose a risk management framework address the steps of identification, analysis, treatment, monitoring and control of risks (Sakao, Öhrwall Rönnbäck and Ölundh Sandström 2013; Herzog, Meuris, Bender and Sadek 2014; Zeiler and Bertsche 2014; Zheng, Ming, Li and He 2015; Palmer et al. 2016; Reim et al. 2016; Kimita, Sakao and Shimomura 2017). Also, the modeling and analysis of risk management through simulation is presented. The frameworks are general, that is, they are not specific for a particular type of PSS. Specific frameworks allow the identification and treatment of specific risks, generating more accurate results.

The best practices were analyzed on a large-scale energy company in Denmark in terms of quality of probabilistic models, quality of data and results, tools and methods used. Challenges with those methods emerged with the clear appreciation of uncertainty due to lack of knowledge and lack of information (Tegeltija, Oehmen and Kozin 2017).

## CONCLUSION

The goal of this article was to conduct a bibliometric study about PSS risk management. A bibliometric approach named TEMAC was adopted to analyze the development track and trend in this overlapping field. This analyze was based on 24 articles and proceedings papers that are related to PSS risk management collected from WoS. The following filters were applied to identify the publications most relevant about the theme: i) language in English; ii) period of 2010 to July 2020; iii) Journals or Conferences, (iv) knowledge areas, (v) lecture of title, keywords, and abstract and (vi) complete reading of the articles. Then, a bibliometric analysis was carried out with respect to the evolution of the number of publications, evolution of the number of citations, main publication journals, nationality of the authors, research area, top 10 cited publications.

So, regarding to the theoretical contribution, this article has identified the main contribution about PSS risk management. The analysis of the 24 articles revealed six main areas of the field as shown in, Figure 12. We found that the area of risk management framework is the prevalent among the studies in PSS risk management, followed by cost estimation/pricing decision and risk perception.

The future research directions identified could be summarized as shown in Figure 5, represented by the six blue rectangles. Immediately below each future direction, there is the respective theme of research.



Figure 5. PSS Risk Management future research directions.

Based on Figure 5, the future research directions means: (i) Explores in depth the mechanism through which different types of PSS influence the customer risk perception; (ii) Research to propose strategies to overcome the customer risk perception throughout the life cycle of a PSS, in order to complement existing studies; (iii) Study the effects of uncertainty over the price of the PSS to adapt it to different market scenarios; (iv) Development of risk management models for specific PSSs considering their phases and activities, because as seen in the article review, the studies researched are focused on general PSSs; (v) Application of risk tools as Ishikawa Diagram, Fault Tree Analysis (FTA) and Bayesian Network to investigate the causes and effects of risks in depth and (vi) Study to address the decision making process to the treatment of uncertainty and risk in the lifecycle of the PSS.

As can be seen, future researchers are directed to studies on specific PSSs, that is, for specific markets. In addition, it seeks to encourage studies that further investigate the risk nature in terms of causes and effects. Finally, it is suggested to consider the entire PSS life cycle in these studies.

This article has certain limitations. There may be some other articles in academic databases that didn't was consider in this study. Moreover, the proposed future research framework was only developed from a conceptual point of view according to the present bibliometric analysis. Nevertheless, this study has mapped the relationships between existing and future research for PSS risk management based on the WoS high quality database. The results provide in contributions for both academia and industry.

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