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Conceptual Framework for Product Service Systems

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Abstract: To remain competitive in the current market, an enterprise must differentiate itself based on higher value propositions. For this purpose, since improving the product or service performance can reach some limits, one potential solution is to move towards new combinations of products and services. This evolution, called servitization, leads to the generation of Product Service Systems (PSS). Servitization requires not only a clear understanding of enterprise core business, but also a clear vision of the prevailing trends and challenges of PSS development from both the business and technological points of view. In addition, the evolution path should be aligned with the enterprise strategy. This paper first highlights the notion of symbiotic PSS where product systems and service systems, and their stakeholders, interoperate seamlessly based on a win-win approach. Then, it proposes a PSS Conceptual Framework (PSS-CF), which can be applied in the early stages of servitization to increase the understating of PSS dimensions and to facilitate the prioritization of the servitization investments. The framework dimensions were discussed in several iterations, from both the academic and industrial points of view, in the frame of a European research project. Moreover, the applicability of the framework was studied in four different industrial use-cases.

Keywords: Product Service System (PSS); servitization; productization; symbiosis; enterprise management; conceptual framework; strategic change

1. Introduction

Enterprise management is intended "to design, control and improve the business processes to adapt to the changing business environment . . . " [1]. In terms of the changing business environment, moving from product-centric businesses towards a service economy is a confirmed change and practicable strategy for manufacturers [2]. Such a movement was originally called "servitization of business" [3]. Servitization leads to the design and development of Product Service Systems (PSS), where innovative combinations of products and services are realized to increase the market share [4,5] or sustainability [6]. Similarly, a PSS can be the result of a productization strategy (i.e., service to product) when the enterprise is originally a service provider. Such backward movement is mentioned in [7]. It should be mentioned that productization does not indicate withdrawing from service initiatives, a process referred to as deservitization by [8].

According to [9], PSS has emerged as one of the most important business concepts for industrial organizations. Regarding the production (manufacturing) system (of a PSS), complexity has been mentioned as a challenge in the development and analysis of such systems [10,11]. PSS not only inherits this complexity, but is also involved in the complexity of service-related activities. In addition, the nature of PSS indicates the necessity of fast and adaptive responses to customer needs, compared to traditional product systems [4]. Due to the PSS complexity and necessity of high reactivity, despite the benefits of servitization, this strategy is not always adoptable [2]. Managers should be more and more flawless in dealing with such strategic matters [12] while making and taking proper decisions and actions on the orientation of investments [13]. Therefore, the following research question can be raised: "How does one support enterprise management in the early stages of servitization/productization?"

To resolve the above question, enterprise management can be guided, with methodologies [14], to successfully conduct the servitization [15]. Over the years, several approaches and models have been proposed to support the various phases of servitization in a company. However, the majority of the works addressing the PSS evaluation phase undertook an operational rather than a strategic perspective. Models supporting strategic analysis of a servitization movement in the decision-making phase are still limited. This preliminary analysis is of fundamental importance for understanding the alignment between the company's business objectives and the possible introduction of a highly complex system like PSS.

A promising approach for bridging this gap while supporting managers in the servitization process is the analysis of prevailing trends and PSS viewpoints. According to Briscoe et al., research on servitization can be studied through different lenses (viewpoints) such as value co-creation and collaboration; systems and networks; information and communications technology; and complexity [16]. Such viewpoints are sometimes identifiable in conceptual frameworks [17]. From a generic perspective, a conceptual framework can be designed based on the key dimensions of a subject or the viewpoints that are to be addressed in the study of that subject. Generally, frameworks or models provide simplified representations of complex subjects and increase the knowledge of the new concepts, as well as the prevailing trends and challenges [18].

With a focus on the aforementioned research question, this paper proposes a PSS Conceptual Framework (PSS-CF), with a devoted methodology, which is mainly developed and validated in the frame of a European research and innovation project [19] and its industrial use-cases. This framework can be applied in the early stages of servitization to provide an understanding of the key dimensions of PSS development for reaching a symbiotic PSS. In such a PSS, there is a high degree of interaction and a win-win and optimized relation between the product- and service-related elements. It should be mentioned that this framework is not a PSS development process or a sequence of activities to be followed in such a process. It is indeed a transverse support that can be applied all along the PSS development process while allowing the servitizing enterprise to define its priorities.

PSS-CF allows on the one hand manufacturers to approach the PSS in a complete way, as it comprises both the business and technological points of view. At the same, its structure, i.e., the dimensions and levels, is easy to understand and apply in many industrial contexts for the early strategic evaluation of servitization.

The methodology adopted to develop this framework is presented in the following section.

2. Research Methodology

As illustrated in Figure 1, this research work was initiated by a preliminary literature review to consolidate the research question. The results underlined "the lack of conceptual approaches with a strategic purpose supporting enterprise managers in the early stages of PSS development", which is a refinement of the initial research question mentioned in the introduction. Consequently, with the objective of developing a PSS conceptual framework, the concept of PSS was analyzed as a whole based on the definitions and classifications proposed in the literature. This allowed identifying the key viewpoints, potentially being the dimensions of the framework. In this context, the viewpoints underline an important characteristic of PSS, a criterion for its classification or a trivial issue in its lifecycle. For instance, a conceptual framework from the business model viewpoint, to assist with the development of PSS, is proposed in [20].

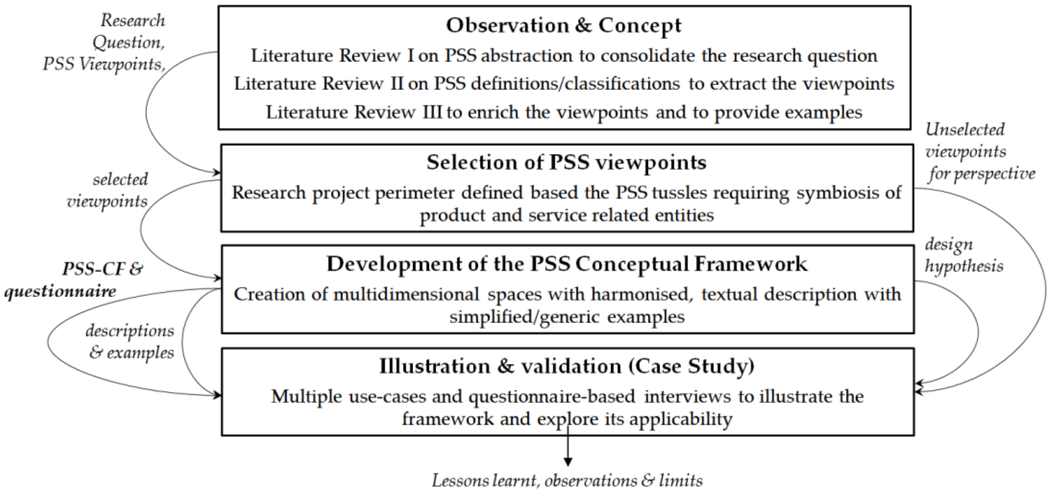

Figure 1. Research methodology. CF, Conceptual Framework.

In the next step of the methodology, the identified viewpoints were synthetized. Each dimension was individually re-studied, according to the literature, to confirm its importance and to provide examples of related research works. The viewpoints were then selected to be included in the PSS-CF considering the perimeter of the research project. The selected viewpoints were structured as a multidimensional space being the backbone of the PSS conceptual framework. The dimensions were also harmonized with four maturity levels, from separated PSS, indicating isolated product- and service-related entities, to symbiotic PSS, which involves a close and long-term win-win relationship between product-service-related entities and often dichotomies around these entities. The designed framework was then extended with a detailed description of the dimensions and layers, as well as simplified and generic examples. Eventually, PSS-CF was applied in four industrial use-cases to validate its dimensions and layers, positioning current and desired positions within each case. Indeed, according to Yin, one of the situations in which a case study is a preferred research strategy is when "how" or "why" questions are being posed [21]. In this research work, the objective of the case study is, on the one hand, to illustrate how PSS-CF can be applied as a strategic support in the servitization process and, on the other hand, to explore and verify its applicability in industrial environments. The conducted case study can respectively be categorized as descriptive (illustrative) and exploratory [21]. Different steps of the case study are illustrated in Figure 2.

Multiple case studies ensure a higher generalizability of results, limiting bias related to a company's characteristics [21,22]. Therefore, to illustrate and verify the applicability of the PSS-CF, four cases with different industrial environments were investigated (see a brief description of the use-cases in Appendix A). The selected cases are manufacturing companies undertaking the servitization process in the following domains: textile (Use-Case 1), office furniture (Use-Case 2), cutting tools (Use-Case 3) and cabin video surveillance (Use-Case 4).

The main objective of using PSS-CF was to apply the use-cases' position in the PSS context, before and after a research project. As a preliminary step, theoretical constructs and concepts were derived from the literature review, mainly consisting here of the PSS viewpoints and layers, as well as related concepts, which guided the design of a questionnaire for interviewing use-case representatives (see Tables A1 and A2 in Appendix B, respectively for the questions and an example of use-cases' answers). Yet, the authors investigated firms' reports to triangulate data from these structured interviews, thus ensuring a higher reliability of findings [22,23]. Based on data collected from these sources, an initial PSS-CF was drawn for all four cases. Lastly, initial PSS-CF propositions were shared with interviewees to get feedback and to reach a common agreement on the concepts.

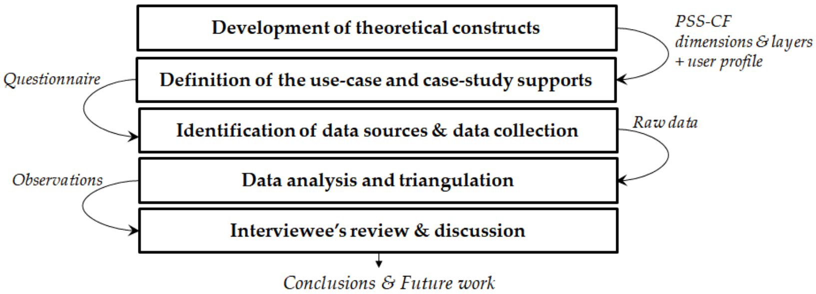

Figure 2. Case study methodology.

3. Literature Review

3.1. PSS Development and Modeling

Servitization can be supported globally by generic or specific PSS development methodologies, facilitating the servitization path, or by conceptualization, abstraction or modelling techniques, which provide an early understanding of PSS ideas [17].

According to [5], PSS engineering, covering the design and development of a PSS, is a process that requires a huge effort. This effort can be in terms of technical specialization/realization, business organization and/or data and knowledge management. This is due to be the complex nature of such PSSs and the necessity of a fast and adaptive way in responding to different customer needs and expectations. In addition, PSS engineering "raises new issues since the service component introduces further requirements than traditional product engineering." [4].

In [4], a research map of the most relevant literature currently available on service engineering and PSS engineering has been created. Their article provides the possibility to understand what has been developed in service engineering research and enables one to identify open research gaps and future challenges. The authors also performed an analysis of the most renowned service engineering process models. An extensive list of phases along the life cycle has been elicited by merging the single proposals. The most relevant phases investigated by these models are mainly related to the beginning of life with a great emphasis on all the requirement activities. Phases, such as Use, maintenance and end of life, have been considered only by recent publications. This indicates their increasing relevance in the development process.

In servitization context, the question of PSS modelling usually arises when an idea of PSS has been formed. Based on [24], PSS engineering might include a set of concepts, frameworks, modelling languages, models, methods and tools. In addition, various representations of a service system at different levels of abstraction to support the design, production, management and delivery of services are presented.

In a recent research work, analyzing several PSS modeling approaches supporting PSS design, the following issues were highlighted: (1) lack of high-level standardization, (2) lack of genericity, (3) specificity of the applications and industrial cases, (4) lack of detailed representation and (5) high level of granularity [25].

While confirming the issues of PSS abstraction highlighted in [25], we believe that they might be less critical in the early stages of PSS design when servitization is still under strategic analysis or when servitization ideas have not yet become design concepts. In fact, in these stages, the modeling approach should be able to conceptually underline the issues limiting the migration from product/service to PSS. Moreover, it should support decision makers in the analysis of their enterprise strategy and identification of potential improvements achievable through servitization.

Another comprehensive study on PSS development shows that most of the approaches proposed in the literature mainly focus on a specific phase of the design process, while to facilitate the PSS development and to harmonize PSS understanding for all the actors involved, a general framework is more beneficial [26]. Therefore, to study the need for such as framework, particularly in the beginning of servitization, we performed a complementary analysis of the PSS modeling approaches based on the stages of servitization covered by them, while indicating the supported task, step or phase in the PSS lifecycle (see Table 1). The results confirmed the statement of [26] and hence indicate the validity of the research question mentioned in the "Research Methodology" section. There is indeed a lack of strategic focus in the proposed PSS development models. Moreover, they usually highlight a specific dimension of PSS development, such as product and service interactions in the final stages of P-S integration, or economic (business model), or environmental issues.

Some valuable state-of-the-art analyses of servitization research, such as the work performed by [27], can be considered as a strategic support for the enterprise management in the early stages of servitization. Such studies provide information about the most significant challenge facing both researchers and practitioners of servitization for efficiently and effectively transforming a manufacturing organization to exploit this opportunity. However, this information can be better structured and presented as a framework with application procedures and examples.

Table 1. PSS development approaches (inspired by [25]).

Reference	Year	Approach	Summary	Lifecycle Focus
[28] [29]	2006 2010	Integrated Life Cycle	A modeling technique based on service lifecycle (integrating product lifecycle)	Lifecycle management
[30] [31]	2007 2009	Service Engineering Service Explorer	Multi-model framework for PSS design Computer-aided service design	PSS design
[32]	2008	Service-Oriented Modeling Framework (SOMF)	Service-oriented life cycle modeling methodology based on the service-oriented modeling paradigm	Lifecycle management
[33]	2009	IPS^2 Metadata Model	A metadata reference model for Industrial PSS (IPS^2) lifecycle management	Lifecycle management
[34] [35]	2009 2011	Extended/Product Service Blueprint	Enlargement of the classical modeling technique "service blueprint"	P-S Integration
[36]	2010	PSS Layer Method	Multi-layer modeling framework to highlight requirements and tasks for PSS design	PSS design (requirements elicitation)
[37]	2009	SLM (Service Modeling Language) and SML Interchange Format (SML-IF)	Constructs for creating models of complex services and systems and a standard for exchanging service models	PSS design (process modeling)
[38]	2013	Functional Hierarchy Modeling	Modeling technique for PSS functions Proposition of a novel PSS typology	PSS design (functional analysis)
[39]	2014	Model-Driven Service Engineering Architecture (MDSEA)	Multi-level architecture and methodology for service system design and development	PSS design and development
[40]	2014	Extended Product Business Model	Methodology to integrate an Extended Product (EP) into the business models	Business modeling
[41]	2016	PSS Multi-View Modeling Framework	A multi-view modeling framework combining product-oriented and service-oriented engineering	PSS design
[42]	2016	PSS Conceptual Structure	A conceptual structure depicting the situation of the literature in the analysis of the economic, environmental and social impact of PSS	PSS evaluation
[20]	2017	PSS Business Model Conceptual Framework	A conceptual framework to support PSS development from the business model perspective	Business model

3.2. PSS Definitions and Classifications

3.2.1. PSS Definitions

In the recent study of Oliveira et al., a comprehensive bibliometric analysis of the PSS research field was performed, which provided an understanding of this domain [9]. Considering this analysis, the PSS definitions proposed by the top five papers regarding citation are analyzed here in addition to the definition proposed by MSEE (Manufacturing SErvice Ecosystem), SusProNet (Sustainable Product-Service co-design Network) and PSYMBIOSYS (Product-Service sYMBIOtic SYStems), which are examples of European initiatives in the servitization context. The analyzed definitions highlighted that PSS can be addressed from the following viewpoints (see Table 2).

PSS can be considered as an economic activity with known market, business model, selling point and economic value [43–46]. PSS is business oriented, and there is a customer willing to pay for the P-S and to participate in the business model. PSS separates business success and economic growth from mere product sales.

Product- and service-related systems and elements are in interaction and integration within a PSS [43,45–50]. The outcome is in fact a mix of tangible products and intangible services, which should interact jointly and symbiotically. In a PSS, the service is not necessarily an "add-on" to the product. Product and service can form an integrated solution, while related entities have different relative importance (e.g., in terms of resources allocation), and one can dominate the other. For instance, a PSS can be service-oriented or product-oriented [51]. No matter the relative importance of product- and service-related entities, there should be a symbiotic (win-win) relation between them to fulfill specific customer needs with higher added values compared to isolated products and services [50].

PSS is designed, combined and provided to the customer to fulfil its needs with a higher value proposition compared to isolated products and services [43,45–49]. Therefore, the benefits of the PSS for the customer compared to mere products or services should be clearly defined. Sometimes, the service contributes/forms the major part of the provided value.

Organizational aspects such as configuration and type of internal and external resources are important issues in PSS [43,44,47–49]. Different types of supports should be combined with product and service lifecycles. PSS is usually developed within a network of enterprises due to the necessity of the involvement of stakeholders with diverse competences and functions. It also requires an infrastructure supporting the usage of the product and the delivery of the service.

Table 2. Synthesis of PSS definitions.

Reference	Year	Viewpoints				
		Economic Activity	**Interaction and Integration**	**Value Proposition**	**Organizational Aspects**	**Sustainability**
[43]	1999	Marketable	Jointly fulfilling	User's needs	A company/alliance	-
[44]	2002	Business models	-	-	Networks, infrastructure	Environmental impact
[45]	2003	Selling	Jointly fulfilling	Client demands	-	-
[46]	2004	Economic value	Jointly fulfilling	Customer needs	-	-
[47]	2007	-	Integrated offering	Value in use	Knowledge, expert	Environmental impact
[48]	2004	-	Jointly fulfilling	Value proposition	Network, infrastructure	-
[49]	2012	-	Interrelated components	Customers	Resource combination	-
[50]	2017	-	Jointly and symbiotically	Customer needs	-	-

PSS contributes to sustainability [44,47]. Environmental impacts are lower than traditional business models, e.g., when a service supports the sharing of the physical products such as vehicles. In fact, servitization might decrease the usage of resources and consequently the negative manufacturing impacts on the environment.

3.2.2. PSS Classifications

In the next step of the literature review, seeking to identify PSS viewpoints, various classifications were studied. These classifications are summarized in Table 3. While initial PSSs were of the type "product-centered", in the course of time, the services became a more important and self-reliant part of the product-service combination. In some cases, the physical product was even aligned with a service or parts of it were replaced by services, e.g., cloud services that replace hardware storage capacity. This development led to enhanced value propositions for the customer and to better options for differentiation in comparison with competitors.

Table 3. Synthesis of PSS classifications.

Reference	Year	Viewpoint
[52]	2000	Contribute to sustainability
[53]	2001	Evolution of product service systems, value proposition
[46]	2004	Product ownership, provider's role in the value production, business model
[54]	2011	Product and service engineering,
[55]	2011	Relationships between product and service design and ICT are used to analyze the data.
[56]	2012	Relationship between products and services (duality vs. unity), products ownership, role technology
[38]	2013	Level of integration and performance orientation of the dominant revenue mechanism within the PSS
[57]	2016	Product type (durable vs. capital goods), service type

3.3. Synthesis of PSS Viewpoints

The PSS viewpoints, extracted from the definitions and classifications, were synthetized into seven categories while enriching them with individual and complementary literature reviews.

The business model viewpoint, depicting the level of integration of product and service business models in a company: This viewpoint includes several others such as economic activity, marketability, selling point, ownership and value proposition. Vargo et al. addressed PSS from this viewpoint. They considered that the manufacturers must be able to clearly define the actual product or service and their value proposition for the customer since it is the core purpose and central process of economic exchange [58]. BM is a confirmed viewpoint and issue in the PSS context [40]. As the product is not adapted to the new BM, it shows the need to adopt a holistic strategic approach to service implementation [59]. Furthermore, according to some interviews, it is considered that existing contracting practices did not reflect the new service BM [59]. Its actual relevance is partially expressed by [60], when stating that the complexity of service BM implementation would appear to lie at the heart of this 'service paradox' (i.e., increasing revenues, though decreasing the actual profit). Hence, the integration of business innovation into the existing business environment is crucial.

The innovation openness viewpoint, defining the perimeter of the PSS ecosystem, as well as the relations of different stakeholders during PSS development: This viewpoint is also related to ecosystem, collaboration, network, organization, alliance and stakeholders. According to Lindberg and Nordin, the following misunderstanding can occur in PSS innovation: "Who's responsible for what when things fail [during or after the PSS development]? [As a trigger of innovation] It is very costly to solve all the problems of responsibilities when things fail." [7]. The relations between the stakeholders in PSS innovation depend on their strategy and the openness of the innovation. The concept of open service innovation has been studied in [61].

The dependency viewpoint, focusing on the strength and the scope of the interaction between the PLM (Product Lifecycle Management) and SLM (Service Lifecycle Management): Viewpoints such as product-service correlation, co-creation and influence are also considered here. Correlations, between the product and services, and by extension the activities producing and delivering them, can be detected all along the P-S lifecycles. It can be about resource allocation, synchronization of activities, etc. Service design should cope with the functionalities provided by the product coupled with that service in a PSS. Therefore, there is a strong need for interactions in P-S lifecycles [62] in both directions. Products are not always optimized to be coupled with services. Thus, it is required to improve the product or service design process and its equipment, with respect to each other, in the case of servitization [59].

The topology viewpoint, representing the level of integration between real and digital world elements: Other viewpoints such as integration, configuration and infrastructure are also relevant here. From this viewpoint, the relation between products and services within a PSS can correspond to different configurations of cyber (so-called digital world) and physical (so-called real world) parts. "Cyber-Physical Production Systems (CPPS) foster new processes and production methods for reducing "time to market", waste and failures, as well as improving quality and cost effectiveness." [63]. From an ICT perspective, tools and platforms can be designed and proposed to the customer as centralized vs. integrated real-digital platforms.

The interoperation viewpoint, addressing the exchange and management of data, information, knowledge and processes within the PSS: Interaction, information and communication also correspond to this viewpoint. The development of interactions between product- and service-related activities can be challenging when actors from various fields of expertise or with different types of resources must exchange information [64–66]. In addition, it is crucial to encompass other types of knowledge, rather than the technical knowledge, as through time, the enterprise learns from its services and gains knowledge (e.g., learning from the maintenance services of a machine) [62]. There is a strong need for information exchange between service and product staff [62]. To resolve these challenges, solutions in the form of collaboration tools or interoperability improvement methods are required [60]. This issue in the PSS context can be addressed more generally by studying the exchanges between the product and service systems in terms of data, knowledge and process sharing.

PSS can be studied under the sustainability viewpoint, which addresses the environmental impacts. Such impacts are usually lower than traditional business models when servitization decreases the usage of resources and consequently the negative manufacturing impacts on the environment. Annarelli et al. provided a conceptual structure, from this viewpoint, depicting the current situation of the literature dealing with the analysis of PSS [42]. A method for sustainability assessment of PSS was proposed by Allais and Gobert while highlighting the socio-economic and environmental context and specific issues linked to small appliances [67].

4. Design of the PSS Conceptual Framework

4.1. Selection of Viewpoints

To design the PSS-CF, among the viewpoints extracted from the literature, we first selected the ones conforming to the scope of the aforementioned European research project, which addresses mainly PSS tussles requiring symbiosis of product- and service-related entities. Therefore, the sustainability viewpoint (environmental issues) was excluded while PSS modelling was added due to its importance, previously mentioned in the Introduction and Methodology sections. This paper is indeed founded on the necessity of PSS abstraction techniques in the early stages of servitization. The modelling viewpoint is also extended to simulation englobing PSS testing and evaluation aspects since simulation is necessary for providing assessments of the PSS performance in terms of dynamicity and behavior since models provide only a static abstraction of the system [18].

4.2. Structuring the Viewpoints as the Framework Dimensions

The selected viewpoints, called dimensions in PSS-CF, were then structured as a multidimensional framework covering two domains (i.e., business and technology) focusing on the main domains of design, development and innovation:

- **Technology-driven domain**: In this domain, the focus is on the type and role of the technology used in the P-S lifecycles from ideation, to design, production and delivery. In addition, the PSS is often "technologically" supported in the provision of expected value to the customer.
- **Business-driven domain**: This domain focuses on the business aspects of servitization or productization, such as enterprise network or collaborations. Moreover, "business benefits and risks" of the PSS for different stakeholders (e.g., supplier and customer) are studied.

The technology and business domains are correlated; each one might constrain the other. For instance, the cooperation strategy (as a business condition) in the enterprise network might limit the choice of suppliers providing the product-service technology.

The framework dimensions are grouped around the above domains while forming a 2 × 3D space (see Figure 3). The link between these two spaces is stablished through two parallel dimensions (i.e., P-S topology and P-S business model) as the core of the framework, since the focus of both dimensions is on the different configurations/combinations of product-related or service-related entities (e.g., lifecycles, processes, resources, etc.).

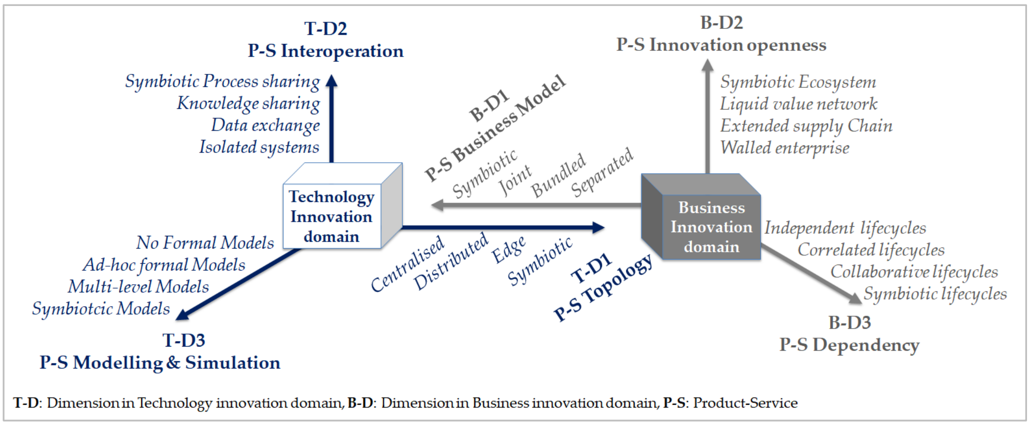

Figure 3. Global view of the symbiotic PSS Conceptual Framework (PSS-CF).

4.3. Symbiotic Maturity Levels

To have a harmonized structure for the framework, four levels were defined, for each PSS-CF dimension, corresponding to different degree of intensity/maturity of the relation between the product (system) and service (system) within a PSS (see Table 4):

1. *Disjoint*: For this configuration, there is no link between the product-related or service-related entities all along the product and service life cycles.
2. *Linked*: For this configuration, some ad hoc or short-term links between the entities can be identified. However, there is no common objective. For instance, a resource, in the product lifecycle, can also be used in the service lifecycle on demand or for a short period of time.
3. *Connected*: For this configuration, we can identify several links between the entities. The links are established with common objectives and based on a collaborative approach. However, the collaboration is not always in favor of both sides (i.e., product and service). For instance, a resource can be shared between product and lifecycles, but it can work only on one side at a time with predefined priority.

4. *Symbiotic*: The last configuration, as the highest maturity level, indicates a close and long-term win-win relationship between product-service-related entities, which often generate dichotomies. For instance, resources can be shared between the lifecycles (P-S), and the assignment is optimized to support both lifecycles.

Table 4. Dimensions and levels of the symbiotic PSS conceptual framework.

	Business Innovation Domain			*Technology Innovation Domain*		
ID	**B-D1**	**B-D2**	**B-D3**	**T-D1**	**T-D2**	**T-D3**
	Business Model	**Innovation Openness**	**Dependency**	**Topology**	**Interoperation**	**Modeling and Simulation**
Disjoint	Separated Business Models	Walled Enterprise	Independent Lifecycles	Separated Cyber-Physical PSS	Isolated Systems	No Structured Method
Linked	Bundled Business Models	Extended Supply Chain	Correlated Lifecycles	Distributed Cyber-Physical PSS	Data Exchange	Ad Hoc Structured Method
Connected	Joint Business Models	Liquid Value Network	Collaborative Lifecycles	Edge Cyber-Physical PSS	Knowledge Sharing	Multi-level Models
Symbiotic	Symbiotic Business Model	Symbiotic Ecosystem	Symbiotic Lifecycles	Symbiotic Cyber-Physical PSS	Symbiotic Process sharing	Symbiotic Models

5. Description of the PSS Conceptual Framework

As mentioned in the previous section, PSS-CF is a multidimensional space constructed based on the key dimensions (viewpoints) to be addressed in the PSS lifecycle. In this section, these dimensions and their layers are presented based on [19] in a more descriptive and illustrative way.

5.1. P-S Business Model Dimension (B-D1)

The Business Model (BM) dimension of the PSS-CF offers four levels, all of which differentiate the relation between products (or established services) and (new) services. The levels are (see Figure 4):

- **Separated**: At this level, the enterprise has separated BMs for products and services where they are offered and sold, sometimes to different customer segments, with separated value propositions (e.g., car and repair services or insurance). The revenue streams for both are independent, which means the customers should pay for each product and service separately. Sometime, there are even separate invoices. Usually, this implies that the key activities regarding the products and services and the required key resources are separated, as well.
- **Bundled**: At this level of P-S BM, the enterprise offers and sells its customers a bundle of products and related services. This is often done in addition to offering the components separately. In many cases, the customers pay one price for the bundle, which is usually lower than for its single components. The bundle products and services might address the same customer, and the customer perceives a "one-face-to-the-customer" approach [68], where all the customer's needs can be met by a single organization. Typical examples are installation, training and maintenance, which can be ordered as "ad-on(s)" to the product.
- **Joint**: At this level, the value propositions of the products and services are still visible as separate components. However, the enterprise offers them only as a combined package. The customers cannot have one without the other, e.g., a product and an extended warranty or a corresponding service hot-line. Other examples are software solutions where the customers should book a maintenance service contract. Renting can be also considered at this level, since the products and services are not separable where the enterprise sells services while renting/leasing products.
- **Symbiotic**: The symbiotic BM represents the highest level in this dimension. The customer perceives one integrated value proposition and pays one price for it. The value proposition can be based on several different product or service components that could change from case to case. For the customer, it makes usually no sense to differentiate between the single components.

If, for instance, the customer pays for the transport from A to B in a defined time, it is generally not very important if this is achieved by bus, train or taxicab (if he/she does not have to change the means of transportation too often with long waiting times). Therefore, the different components of the PSS form a "community", supporting each other in a symbiotic way. This should be considered in the BM, as well. It is important to share the economic benefits and risks between the contributors in an appropriate way. These benefits can be achieved by increased sales based on the network (or symbiotic) [69]. This means the more users apply the same standard of products or services, the more the added value will grow.

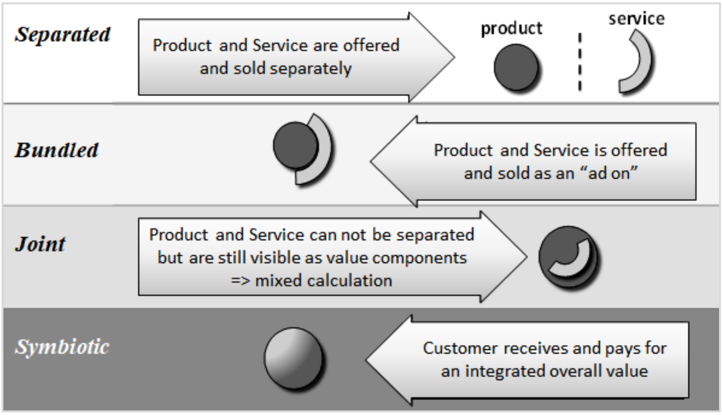

Figure 4. Levels of the "P-S business model" dimension.

5.2. P-S Innovation Openness Dimension (B-D2)

In the product and service lifecycles, the stakeholders can have different degrees of involvement. This also defines the perimeters of the PSS ecosystem:

- **Walled enterprise**: The PSS lifecycle is managed by one enterprise. Innovation is closed and is done internally.
- **Extended supply chain**: Several enterprises collaborate in the PSS supply chain for producing, delivering and innovating the product and service. Here, the PSS lifecycle is in collaboration with the supply chain. This level looks into traditional hierarchical tier-based chains.
- **Liquid value network**: The collaboration is not only in the supply chain, but also in the PSS value chain. In this case, customers and consumers are actively involved in the PSS value chain and P-S innovation process. Here, the term "liquid" indicates a border-less enterprise looking into peer-to-peer value networks (virtual enterprise). The liquid enterprise model proposed within the OSMOSE (OSMOsis applications for the Sensing Enterprise) European research project represents an example of this level of P-S innovation openness.
- **Symbiotic ecosystem**: This indicates several partners around the PSS lifecycle and P-S innovation process, including suppliers, manufacturers, service providers, research, innovation entities and even the government. Here, a PSS ecosystem is formed.

5.3. P-S Dependency Dimension (B-D3)

This dimension indicates the way the PSS BoL (Beginning of Life), MoL (Middle of Life) and EoL (End of Life) activities (design, engineering, usage and recycling) are conducted and how actors (designers, engineers, manufacturers, users, etc.) interact with each other:

- **Independent lifecycles**: This indicates different teams and independent projects and processes for product and service.

- **Correlated lifecycles**: This happens when we still have different teams, but there is a kind of relation between them. The relation can be through communication, shared resources and feedback loops or rendezvous points. Despite such links, the strategic or tactical objectives are not common.
- **Collaborative lifecycles**: This requires a common and single objective for product and service design and development. In this case, the development teams are mixed, and they share their resources, but also, they support each other all along the process through co-operative work.
- **Symbiotic lifecycles**: This involves open and agile teams with frequent interactions. A single product-service team can be formed for designing products or services.

5.4. P-S Topology Dimension (T-D1)

This dimension depicts the alternative configurations of a PSS according to the degree of connection between physical, so-called "real-word", and cyber elements, so-called "digital-world":

- **Separate cyber physical**, where the PSS centralized cyber components are not interconnected with the physical ones; the physical product is just as a (passive) source of data.
- **Distributed cyber physical**, where the PSS distributed cyber components can communicate with physical ones by means of an intermediate center. The physical product can provide and store data.
- **Edge cyber physical**, where the PSS cyber and physical components extensively communicate. The physical product can collect, store and filter data. Wearable devices for medical monitoring represent a good example of edge cyber physical PSS.
- **Symbiotic cyber physical**, where the PSS cyber and physical components are integrated. The physical product can collect, filter and store data, as well as send alarms and notifications. CPS (Cyber Physical System) for predictive maintenance is considered as one possible example of this level.

5.5. P-S Interoperation Dimension (T-D2)

In PSS-CF, there are two dimensions that consider the cooperation and exchanges among partners; one is focused on the business innovation side, which is called the "P-S innovation openness" dimension (see Section 5.2), and the other one is focused on the technical innovation side, which is called the "P-S interoperation" dimension. Generally, the technical dimension of interoperation provides the means for cooperative business processes, especially when it comes to open innovation processes. It emphasizes the data, information, knowledge and process exchanges and their management between the partners or PSS components. This means that "partners" do not necessarily have to be different, legally independent enterprises, but could also be different departments or other organizational units within one enterprise.

The levels regarding the technical dimension of "interoperation" are (see Figure 5):

- **Isolated systems**: In this situation, product and service Lifecycle Management (LcM) IT are separated. In fact, individual information systems and databases exist for product and service.
- **Data exchange**: This happens when product and service LcM IT (mainly information systems) can communicate with each other through data exchanges. Here, interoperability between systems reaches a technological level.
- **Knowledge sharing**: In this case, communication between product and service LcM IT goes beyond simple data exchange. In fact, processed and reasoned data, knowledge or sentiment can also be exchanged. There are broad options to not just exchange data, but to get access to data. Here, the IT systems are interoperable technologically and semantically.
- **Symbiotic process sharing**: When product and service LcM IT use a single data model and are fully interoperable while sharing processes, they are considered at this level.

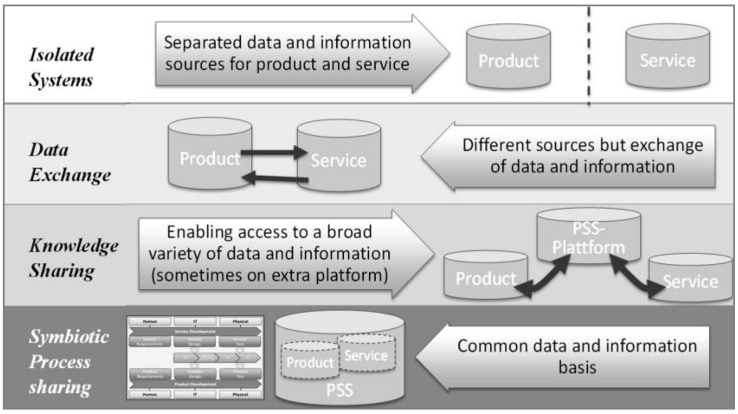

Figure 5. Levels of the "P-S interoperation" dimension.

5.6. P-S Modeling and Simulation Dimension (T-D3)

Product-service-related models may exist in different forms (e.g., product or service data model, physical or business process model, system model, enterprise architecture, etc.) with drivers modeling supports. The Modeling and Simulation (M&S) dimension highlights the usage of these models, modeling, simulation or test supports (e.g., formalisms, languages and tools) and the methodology behind them in the P-S lifecycle:

- **Models with no structured method**: This level corresponds to a lack of M&S support with structured methods or standard concepts, for the representation of product-service-related objects. Some graphical representations or models might exist, with no commonly-accepted structure, just to present a simplified vision of an object. In such models, the links between product and service are not formally described. In addition, models are not simulation-ready.
- **Ad hoc models with a structured method**: This level indicates the existence of M&S support for products or services with known, shared, standard or structured coupling of modeling languages/techniques. At this level, models can be simulation-ready or dynamic, but there is no link between product simulation and service simulation. The Unified Modeling Language (UML), which is a general-purpose modeling language in the field of software development [70], and Graphs with Results and Actions Inter-related (GRAI), which is a structured modeling method of Enterprise modeling [71], can be mentioned as examples.
- **Multi-level models**: This level conforms to the availability of M&S support with different abstraction levels in the P-S value chain. The levels can correspond to different granularities or different perspectives of the same object; from global to local, from business to IT, or from static to dynamic. In some modeling languages such as IDEF [72], process models can be elaborated with a bottom-up or top-down approach to illustrate a process at its global to local levels based on the granularity of the activities. As another example, the Model-Driven Service Engineering Architecture (MDSEA) [39], developed based on the model-driven architecture [73], considers different linked layers with business or technological views of the (product-service) system. At this level of modeling, models can be simulation-ready or dynamic, while there is a link between product simulation and service simulation, but not in a joint or optimized way.
- **Symbiotic models**: This level indicates the models or M&S support in the value-chain that bridge product- and service-related elements (e.g., lifecycles). For instance, a symbiotic process model can include both the design of the product and service, as well as the interactions (information or physical flows) between the two design processes. Therefore, product and service lifecycles are usually represented in a single model. A unified decisional model for controlling the P-S lifecycle is proposed in [17]. At this level of modeling, models can be simulation-ready or dynamic, while the simulation is done in a joint way on the product and service to find the optimized scenario.

6. Case Studies

6.1. PSS-CF as a Strategic Support for Enterprises

In this section, the strategic application of PSS-CF in the aforementioned four use-cases is illustrated. From a generic point of view, the priority of a topic (e.g., PSS-CF dimensions) in the enterprise strategic actions (e.g., a financial investment, participation in a research project, servitization, etc.) can be defined based on different indicators such as: expected evolution, indicating the gap between the initial and expected position of the enterprise; relative importance, or the priority, related to the enterprise's willingness to study or invest in a topic; probability of evolution, indicating to what extent a desired position is possible to reach; return on investment, indicating the profit of the evolution considering the required investments and usage of resources.

In this paper, the focus is on the first two indicators while considering servitization as a strategic action for the enterprise PSS evolution. In fact, once PSS-CF and its dimensions are understood by an enterprise, it can be applied, in the early stages of servitization, to define the evolution path for the PSS to be realized. This can guide the next stages where PSS ideas are evaluated, developed and eventually commercialized.

6.1.1. Expected Evolution

To study the Expected Evolution (EE) of each dimension, at first, use-cases' positions (i.e., in the beginning of the servitization project (as-is position) and the position to be reached by the end of the project (to-be position)) were defined.

The position in "disjoint", "linked", "connected" or "symbiotic" levels of PSS-CF dimensions (see Figures 6 and A1 in Appendix C) is respectively quantified from 1–4. Therefore, EE of a dimension, being the gap between the initial and expected positions of a use-case, can be quantified from 0–3 (excluding a negative gap or backward evolution, which is logically not desired and should be further investigated): "0" indicates that the enterprise is not willing to evolve its PSS in the dimension or the highest maturity level is already reached; "1", "2" or "3" indicates that EE is respectively low, medium or high.

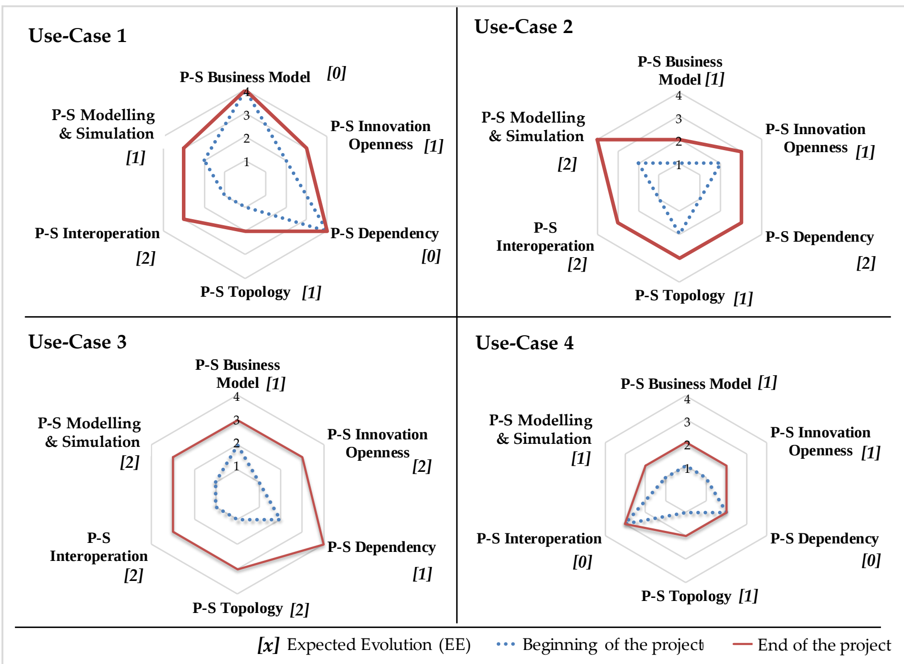

Figure 6. Expected Evolution (EE) of PSS-CF dimensions.

Considering the results of use-case positioning in PSS-CF, based on EE, it can be observed that:

- Use-Case 1 is mainly willing to move from an "extended supply chain" to a "liquid value network", which indicates moving from traditional hierarchical tier-based chains to a border-less enterprise looking into peer-to-peer value networks and active involvement of customers and consumers.
- As a part of Use-Case 2's innovation strategy, the enterprise is mainly willing to move from linked to collaborative P-S lifecycles where the design teams are mixed and share their resources. Additionally, they support each other all along the process through co-operative work.
- Use-Case 3 requires moving from "isolated systems", where individual P-S information systems and databases exist, to "knowledge sharing systems", where processed and reasoned data, knowledge or sentiment can be exchanged between P-S information systems.
- As a part of the innovation strategy, Use-Case 4 is willing to move from "separated" to "bundled" in the BM dimension. Initially, this use-case handles services generally independent of the initial product, the video surveillance system. As a result, the use-case considers an innovation path for the new PSS that starts with services as an "add-on" to the current product. Use-Case 4 also intends to apply the "ad hoc modeling and simulation with structured method", which indicates the existence of models for products or services with known and standard M&S languages with structured supports. Therefore, the enterprise confirms an investment in this dimension that should be studied in its innovation strategy.

6.1.2. Relative Importance

In the second strategic analysis, to verify the results of the evaluation of EE, mentioned in the previous section, use-cases were directly investigated to define the Relative Importance (RI) of a PSS-CF dimension. This indicator can be quantified as low, medium or high, which are respectively quantified from 1–3 (see Figure 7).

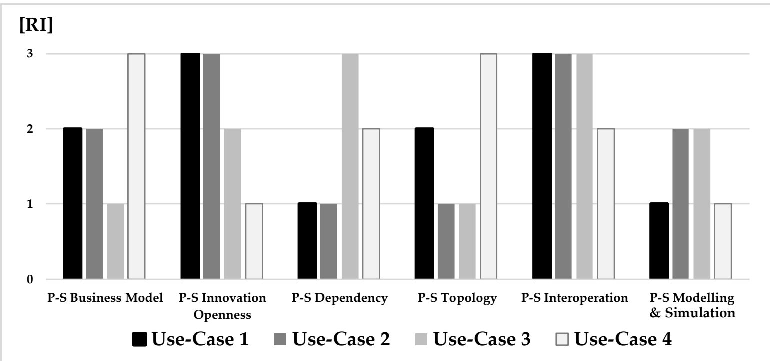

Figure 7. Relative Importance (RI) of PSS-CF dimensions.

6.1.3. Expected Evolution vs. Relative Importance

In the following points, some observations are formulated for each use-case considering the coherence of the evaluated EE and RI of the dimensions (comparing Figures 6 and 7). It should be noted that coherence means that the dimensions with higher RI should have higher EE:

- In Use-Case 1, there is a coherence between EE and RI of the dimensions. For instance, the "innovation openness" and "interoperation" dimensions are selected as highly studied (Scale 3). In other words, the use-case intends to focus more on them. At the same time, it expects to evolve in these dimensions, particularly in the P-S interoperation, since there is a gap between the position in the beginning and at the end of the project.
- In Use-Case 2, it is observed that there is small incoherence between the EE and RI of the dimensions. On the one hand, Use-Case 2 mainly focuses on "P-S innovation openness"

and "P-S interoperation", as they have been selected as highly studied (Scale 3). On the other hand, the greatest evolution within the project is expected for the "P-S modeling" and "P-S interoperation" dimension. This can be explained since the modeling dimension can be considered a supporting competence for properly addressing both P-S innovation openness and P-S topology. In other words, advanced modeling tools and skills within the company will ensure huge benefits in dealing with the other two dimensions.

- In Use-Case 3, EE and RI of the dimensions are almost coherent. Use-Case 3 focuses mainly on "P-S dependency" and "P-S interoperation", so that these two dimensions are selected as "highly studied" (Scale 3), and considerable development is expected for them within the project. From a generic point of view, Use-Case 3 shows the largest overall EE from the beginning to the end of the projects among the use-cases.
- In Use-Case 4, EE and RI of the dimensions are almost coherent. "P-S business model" and "P-S topology" are identified as "highly studied" (Scale 3), meaning that Use-Case 4 is focusing more on these dimensions. These dimensions show the lowest value of company characterization at the beginning of the project (Level 1, respectively "Walled enterprise" and "separate cyber physical"). Therefore, larger room for improvement can be considered for them; as confirmed by Use-Case 4, the expected status at the end of the projects (Level 3 for both dimensions).

6.2. PSS-CF as a Structure for the Research Project Results

Besides being a strategic support, PSS-CF can be applied during a research project in the servitization context to analyze the requirements of initial end-users (i.e., use-cases, pilots or trials), to structure the results (i.e., knowledge, methods and tools) provided to them by the project and to verify the coverage of the PSS dimensions. This can clarify the exploitation capacity of the project.

6.2.1. Overall Analysis of Project Use-Cases

In our research project, from a global perspective, use-cases show a higher focus on "P-S interoperation", which has been indicated as almost "highly studied" (2.75) (see Figure 8). Nonetheless, it is observed that "P-S dependency" is the dimension with the largest EE within the project (from 1.5–3), followed by "P-S interoperation" and "P-S modeling" (from 1.5–3). However, at the end of the project, characterization of the use-cases along the six dimensions will be extremely balanced, ranging from 2.5 ("P-S topology") to 3 ("P-S interoperation" and "P-S modeling").

The four use-cases showed that the servitization process asks for a step beyond the disjunction of product and service in each dimension. This evolution appears particularly fierce in P-S interoperation, since companies should establish regular and structured knowledge exchanges between product and service businesses (Level 3, "connected"). Furthermore, only "P-S dependency" and "P-S business model" present cases willing to reach the "symbiotic" level in the "to-be", respectively Use-Case 1 and Use-Case 3.

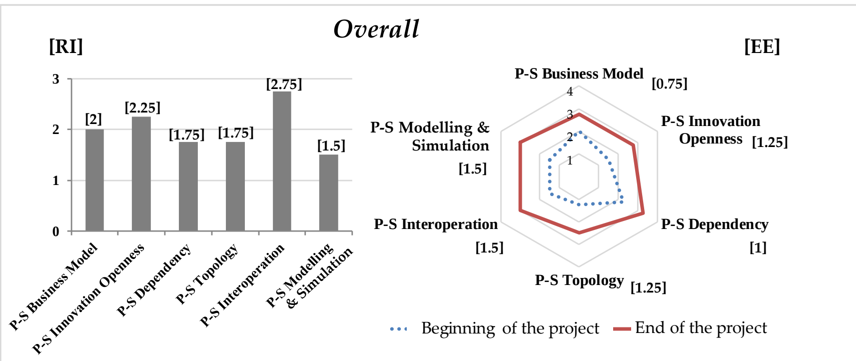

Figure 8. Overall Relative Importance (RI) and Expected Evolution (EE).

6.2.2. Categorization of Project Results

During our research project, several solutions were developed and applied to the use-cases to support their servitization path (see Figure 9). As mentioned in the previous section, PSS-CF indicated how a use-case expects to evolve in a dimension (moving to a higher level) using the project support. Here, the focus is on the project results applied by the use-cases to reach the EE.

It was observed that the project supports use-cases in improving their positioning in almost all the dimensions (average 5.5 out of 6). On average, the project IT tools and platforms help companies in coping with almost five dimensions while the project provides structured methods for almost three dimensions.

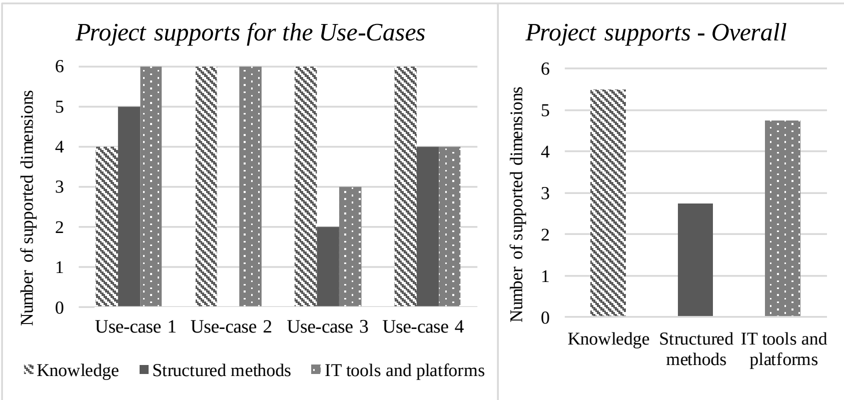

Figure 9. Project supports for PSS-CF dimensions.

By focusing on single use-cases, it can be observed that supports provided by the project vary. In Use-Case 2 for example, the project widely provides relevant knowledge increase and IT tools, while structured methods are not relevant for improvements along the six dimensions. On the contrary, Use-Case 1 heavily relies on structured methods for improving five out of six dimensions.

7. Discussion

For manufacturing companies venturing into the first steps on the servitization roadmap, it may be difficult to imagine how an integrated approach of product and service elements could support the strategic goals efficiently. If service tasks, roles, units and organizational structure are still developing and emerging from the product business activities, the design of product-service cooperation is also promising, as the way is unclear. For these companies, it seems to be important to understand their current status of product-service interactions and dependencies at first, before starting to design integration activities.

Considering the above issues, the main objective of this paper is to support the researchers, working in the PSS context, or enterprises, willing to move towards servitization/productization, with a conceptual reference and a theoretical ground. Based on an extensive literature review, this paper first underlines the prevailing dimensions of PSS that should be considered during servitization. Such dimensions, focusing on different products-services, should be understood in the upstream of servitization and should be considered all along this process, on the one hand, to ensure the respect of the enterprise strategy and to guide the PSS designers for developing PSS based on symbiotic P-S interaction. In the current market, it is of utmost importance to go beyond traditional PSS through the creation of symbiotic ones where the benefits and risks are shared between the contributors in an optimized way.

To structure the PSS dimensions selected in this paper, while focusing on the symbiosis of product- and service-related entities all along the product-service lifecycle, a framework called the symbiotic PSS Conceptual Framework (PSS-CF) is proposed. The framework and its dimensions, designed as a multidimensional space, are described to provide structured knowledge to the servitizing enterprises. For validation purposes, the results were discussed in several iterations with research and industrial experts in the frame of a European research project. This allowed ensuring a preliminary validation within the project consortium as a pilot community.

Besides the conceptual contents of PSS-CF, it can be used as a strategic support for enterprises in the early stages of servitization or as a structure for research projects in this domain. Concerning its managerial implications, pure manufacturers willing to introduce services are aware by means of the proposed framework of all business and technical areas of the company potentially affected by this strategic shift. This might help them in reducing the risk of unexpected outcomes from the servitization projects, leading to poor results. Indeed, by knowing where the servitization project might impact, companies are able to set up proper risk management resources and actions from the very early stages, with a significantly lower cost than ex-post actions. In addition, PSS-CF represents valuable support for defining priorities among the number of investments a servitization process demands. Particularly for SMEs, whose innovation projects are usually hindered by a limited access to credit, knowing areas and processes in which to invest first when shifting to PSS is a critical issue.

In addition to the stated advantages of PSS-CF as the key contribution of this research work, the overall research methodology can be also considered as a contribution. This methodology can be followed to develop similar frameworks in the domain or to enrich the current PSS-CF.

8. Conclusions

To verify the applicability of PSS-CF, the framework was studied with four industrial use-cases through questionnaire-based interviews and the firms' reports. It was mainly observed that:

i. Having understood each dimension, use-cases were able to define the gap between their current and desired positions (i.e., EE) where the passage between them indicates their evolution path.
ii. The Relative Importance (RI) and Expected Evolution (EE) of dimensions are globally aligned in the use-cases. Misalignments require further investigation to ensure the coherence of investments for servitization with enterprise strategy and priorities.
iii. Use-cases indicated higher EE in the "P-S dependency" dimension, which could be explained in light of the transaction cost economy [74,75]. Strategic shift towards a PSS increases the actors involved, as well as the number of interactions required, so that higher transactional costs might occur. Particularly, a shift to a more extensive exchange of information is an attempt to cope with this higher complexity, reducing potential asymmetries within the P-S ecosystem.
iv. Use-cases consider "P-S interoperation" highly important. This could be explained according to Resource-Based View (RBV) theory where the servitizing company wants to optimize the bundling of product and service by exploiting synergies between resources. In RBV, a company evaluates its resources, capabilities and plans for maximizing long-term competitiveness [76–78].

The application of the framework to the four case studies showed that for some PSS dimensions, specific actions were not necessary, revising the initial idea of companies having to completely review processes, structure and resources in the company. This allowed the companies involved to focus on more targeted actions for introducing PSS in their business model.

Despite the relevance of the outcomes achieved, some main limitations might be identified in PSS-CF. First of all, it should be noted that the proposed framework has been designed and elaborated in the specific frame of a European research project, which was seeking to underline the importance of symbiosis in the interactions of product- and service-related elements. In this project, although the application of four case studies was defined and followed by a predefined protocol to cover several industrial sectors and classes, it does not allow one to completely limit potential biases of the companies studied. Furthermore, PSS-CF does not deal with performances measurement since it does not provide a grid of quantitative KPIs alongside the six dimensions. To cope with the limitations of PSS-CF, it can be exploited in further works with a survey through collaboration with industrial or research communities such as European PSS clusters. This action allows performing a further validation of the framework applicability, enrichment of the concepts with additional examples and inclusion of new dimensions (e.g., sustainability). Considering PSS-CF as a strategic support, indicators, such as probability and return on investment (as mentioned in Section 6.2), could also be investigated in the future. Finally, the hypotheses in the design of the questionnaire (e.g., equal weight of the dimensions in terms of investment effort) and quantification of the results can be also mentioned as a perspective axis.

Author Contributions: All authors have contributed to the intellectual content of this paper. A.P. conducted the writing of the paper. S.G. was at the origin of addressing PSS from different viewpoints and levels. A.P. and M.S. performed the literature review with the support of G.D., I.W. and L.G., A.P. and G.D. designed the initial structure of PSS-CF which was then consolidated with the support of M.S. and S.G. The naming and definition of concepts (e.g., framework dimensions and levels) were discussed and decided by all the co-authors. A.P. and M.S. designed and conducted the case-study with the support of C.H., M.J.N.A., A.C.E. and A.L., as use-case representatives. C.H. and M.J.N.A. revised the submitted version. A.P. and M.S. performed the final revision.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The following use-cases were involved in the research project at the origin of this paper contributions, namely PSS-CF.

Use-Case 1: This is a case in the textile industry. The textile value chain is characterized by the production and treatment of unfinished goods in B2B business relationships. It is very fragmented and distributed in a plethora of very small specialized subjects, usually sub-suppliers, working for a few relatively larger fabric producers (wool mills), of medium dimension, mid-caps mainly. Especially in the case of high-value textiles, the design of new product catalogues (collection) has recently implied a transformation for EU textile companies into “product-service” suppliers, since even the highest quality textile production would now become empty and worthless if disjointed from a close symbiotic collaboration with the stylists of the clothing, in order to personalize fabrics (exclusive textiles) and to support them with the design of extremely customized products. Being an industrial end user, the enterprise involved in this use-case was supported by the research project in the development of the Virtual Design Office and Virtual Showroom Tools.

Use-Case 2: This is related to an enterprise in the furniture industry that offers a user-centric office furniture renovation product-service considering the sentiment and the experience of the workers at the office. The most relevant features are: monitoring of the furniture usage, analysis of postural health through sensors that detect the wrong habits through sensors, detection of not-recommended ambient situations in the office, collection and analysis of opinions and sentiments of the workers towards the furniture in use, assessment of the brand value of the customer company, analysis of social media resources to support the generation of innovative ideas, integration of eco-impact information in the interior decoration projects offered to the customer company and the generation of reports on data gathered during the previous analysis. Therefore, the workers gain awareness of the office conditions, so they could take preventive and corrective measures, improving the well-being of the employees, and the furniture manufacturers obtain valuable information about the use of the furniture in the office environment, enabling the generation of improved decoration solutions.

Use-Case 3: This involves an enterprise in the cutting tools industry. Cutting tools are an integral part of any manufacturing process, even in an advanced machining or drilling processes (aeronautics, automotive), or more traditional manufacturing sectors (plastic, wood-based manufacturing). In any case, the use of cutting tools is at the very core of achieving the functionalities of the product. The involved enterprise manufactures and commercializes precision cutting tools and thread rolling tools. It wants to move from its current traditional business model to a product-service-oriented business model. The objective of servitization in this use-case was to offer a whole product service, being a fast commercial proposal including tool design, budget and delivery date, agile remote stock control with smart cabinets and quality reports on customized precision cutting tools' performance. The main benefit for the enterprise is the acquisition of optimized knowledge management and therefore greater agility in design, planning and manufacturing processes, which allow it to offer these smart value-added services and lead to higher customer satisfaction.

Use-Case 4: This concerns a solution provider, which offers high-tech video surveillance systems in the aviation industry. The enterprise already offers consulting services (e.g., for the design of video systems in aircrafts), but the servitization idea of having bundles of tangible products and intangible software-based services appeared to be promising for achieving the business goals. First, it makes the product range more attractive by new business models and smart, value-adding services. Second, selling services opens up a promising potential for after markets sales, which enables more continuous revenues. Finally, the existing product range becomes much more adaptable to customer wishes as the development of software-based service requires significantly less development efforts. The research project, supporting the servitization strategy of this use-case, offered various methods and tools to develop the "right" product services. However, most importantly, the project prepared the enterprise for future market demands, and it enabled it to assess the potential of its product services with respect to risks and gains.

Appendix B

In this Appendix, a simplified version of the questionnaire supporting the application of PSS-CF and an example of the use-cases' answers are presented.

Table A1. PSS-CF questionnaire (simplified version[1]).

Relative importance of the dimensions
Q1. Which dimension is (will be) studied more in your company? *
Position of the use-case in a dimension before the project
Q2. How would you characterize "Dimension X" of your company at the beginning of the research project?
Position of the use-case in a dimension after the project
Q3. How would you characterize "Dimension X" of your company at the end of the research project?
Project supports for the use-case in each dimension
Q4. How does the research project support you in analyzing and developing "Dimension X"?

* This question was asked separately for each domain (business/technology).

Table A2. Example of answers to the questionnaire regarding the business model dimension.

		Dimension "B-D1, P-S Business Model"				
		Question 1	**Question 2**	**Question 3**	**Question 4**	**Question 5**
Use-Case	**1**	Moderately studied	Joint	Symbiotic	To provide IT tools and platforms	Virtual design tools
	2	Moderately studied	Separation	Bundling	To increase knowledge about this dimension, To provide IT tools and platforms	n.a.
	3	Lowly studied	Bundling	Joint	To increase knowledge about this dimension, To provide structured methods	n.a.
	4	Highly studied	Separation	Bundling	To increase knowledge about this dimension, To provide structured methods	Business model and risk analysis methods

Appendix C

To have a better understanding of the use-cases' Expected Evolution (EE), their positions were projected on the PSS-CF (see Figure A1).

[1] The complete questionnaire is accessible here: https://goo.gl/forms/JAgqaHkRwq8Tg1wH2.

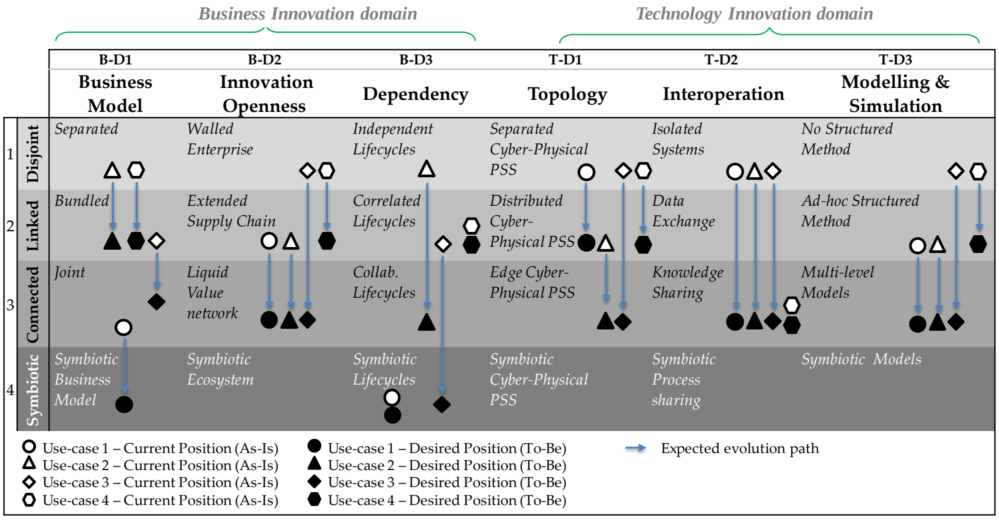

Figure A1. Use-cases' initial and expected position in PSS-CF.

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