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Design Preconditions for Product–Service Integration

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Abstract: User expectations regarding new products and services are evolving rapidly, forcing innovative organizations to explore new avenues for innovation, combining products and services. This paper focuses on the integrative design of product–service systems (PSSs) and builds on the servitization and service-based innovation literature. Many tools have been proposed for designing integrated PSS, with the intent to generate economic and/or sustainable impact. In this article, we focus on tools being used for bringing the user experience and intangibles in the design process. Although the literature is rich with tools and methods to optimize the PSS design process, it does not consider the full array of methods and their impact. This lack of research attention might hinder organizations developing PSS. Using in-depth interviews, this qualitative research systematically combines the extant conceptual literature on PSS design tools and processes with expert insights, thereby contextualizing how to lower thresholds in PSS design processes and how to increase the effectiveness of PSS design tools. The paper contributes to the literature on servitization and PSS by explicitly identifying twenty-one preconditions that support the PSS design process while integrating product and service innovation in close relation to the end-user.

Keywords: product–service systems; integrated product–service innovation; integrated logic; design process; front-end of innovation; user experience; value creation

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1. Introduction

On a daily basis, social and psychological aspirations and environmental concerns push user expectancy levels toward new horizons. As a result, organizations are systematically rethinking their business models [1]. One of these innovation and transformation routes is the development of a product–service system (PSS), i.e., the design of integrated systems of products and services delivered by one or more socioeconomic partners and designed to fulfill a specific customer need [2,3]. Boehm and Thomas [3] accentuate the integrated nature and the centrality of the end-user when developing a PSS: "A PSS is an integrated bundle of products and services which aims at creating customer utility and generating value". Despite the fact that an increasing number of companies are actually offering bundles of product and service elements [4], and notwithstanding the huge amount of academic literature on the subject [3], companies still seem to struggle with the execution of PSS design. There seems to be limited focus on how product and service elements should be combined in the design process [5].

Velo Antwerp serves as a typical example of PSS (Figure 1). This bike rental system helps people in unforeseen situations, or routine situations to travel short distances between two given locations in the city (e.g., closing the gap between public transport and the final destination). The apparent set of products, related services and the system behind it pro-

vides clear interactions with the end-user, and the direct consequences for the ecosystem's stakeholders responsible for availability, tracking, maintenance, and asset management.

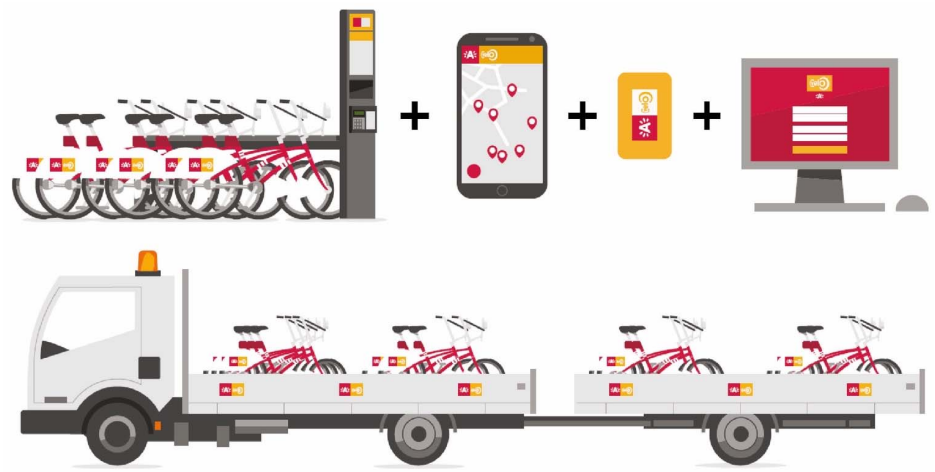

Figure 1. A product–service system (PSS) example, velo Antwerpen (courtesy to Vancoppenolle W., APBClass, 2019).

As shown in this example, a PSS is a complex combination of physical, immaterial and digital elements that needs to be combined. Companies and institutes use a variety of methods to bring in an integrated process combining views from users, stakeholders and ecosystem partners in the design process. To that purpose, they use a set of design tools. However, what do we actually know on their effectiveness? When do we use specific tools during the design cycle? What are the preconditions for the optimization of an integrated PSS design process?

For instance, Coreynen et al. [6] identified barriers that prevent companies from upscaling to an integrated PSS approach. A first important barrier is the lack of knowledge, processes, and experience to develop fully integrated PSS, coined as the PSS "design" barrier. As a consequence [7], these companies introduce services such as customer support, product upgrades and loyalty programs, as add-ons and perceive them rather as a liability than as an economic potential [8]. The extant literature on PSS shows substantial efforts in design methodologies and encompassing frameworks that bring in the service perspective, providing methodological guidance and operational/decision support tools to enhance the PSS design process [4,5,9–11]. However, despite their existence, the tools often do not seem to provide the required support to speed up the design process and develop the intended integrated product- and service-innovation [12]. Authors [13–15], offer a variety of tools to feed and strengthen the PSS design process, but a connection between various tools, the process and their impact on the result might be less clear. A second barrier identified by Coreynen et al. [7] is the organizational mindset required for developing or implementing integrated PSS design due to a historical background limited to only product development and an inherent distrust in the potential of PSS. Coreynen et al. [6] refer to this issue as a PSS "logic" barrier. When a service and customer-centric mindset is reflected in the behavior of the organization and its management, it might be easier to integrate customer experience in the PSS design process and as such develop solutions that matter. Authors in the field discuss potential readiness for servitization [4,16,17], but provide little consideration to how organization, management and design teams can undertake the challenge to make an integrated logic actionable [18] in the design process.

Prior research on service innovation has been pointing at three distinct PSS design streams [19–22]. The assimilation stream looks into service innovation as an extension of the existing business [23–25]. The companies are not familiar with integrated PSS design methods, thereby considering the service element as add-on to an already designed product [8,26]. Consequently, the full potential of the service value potential is not real-

ized. Secomandi and Snelders [27] point out that this fixation on goods is understandable considering design's historical role, but underpin the necessity to tackle the half-hearted integration of services. As a clear answer to this, the demarcation approach progressively addresses the customer's needs and experiences, focusing on the way interactions are made meaningful throughout the entire lifecycle of the product–service offering. Well-established methods and processes put a user perspective central to the design and development of services, with its unique set of characteristics [23,28–30]. However promising each of the above approaches, they persist in under-addressing the integrated character of PSS innovation [18,31]. However, service and manufacturing activities are becoming increasingly intertwined, creating the need for a more integrative product–service innovation model. In this paper, we follow a synthesis approach [29,32,33] that transcends the dichotomy between technological and non-technological forms of innovation. This approach aims to merge assimilation and demarcation, thereby bridging product and service features [28]. Incorporating the rationale of synthesis, we focus on the importance of integrated PSS design in the front-end of innovation (FEI).

As pointed out by prior research [34,35], FEI decisions have a major impact on both the product and the service parts of the intended offering. The interaction between both elements (product and service) must be fully considered during the design process. Every process step following the FEI is shaped and determined by the outcome of the first design stages [36]. As such, a lack of coordination and connection between product and service attributes leads to sub-optimal results [37]. An early integration in the front end of products and service design is supposed to yield significant benefits but this can only be achieved when companies optimize their front-end integrated PSS design. A lot of tools have been suggested to accomplish this.

Notwithstanding all the literature [4,38,39] suggesting different design tools and their usage, as well as approaches to optimize design processes, we claim that product–service integration cannot be optimized until one can link PSS design tools to process steps preconditions. Undoubtedly all PSS design tools are meant to enhance effectiveness in design steps, but it is unclear to what extent these tools (can) effectively improve, simplify, or facilitate the process, overcoming the PSS "design" and PSS "logic" barriers. We aim to contextualize how thresholds in PSS design processes can be lowered and how design tools used can become more effective throughout the different design stages.

We build on input from practitioners and synthesize relevant concepts and frameworks necessary for PSS design and pinpoint useful directions for implementing PSS. Given the exploratory nature of the study, we collect insights on the cognitive frames of designers and design experts that effectively follow an integrated design logic, which supported design teams and used a variety of PSS design tools. We asked these experts to look for blind spots in the design process and relate these to a set of PSS design tools brought together in one eclectic overview [40], and used as stimulus to discuss with experts how the use of tools might miss the desired effect in case preconditions to the PSS design process are not met. As such, we do not intend to test this specific toolkit.

We identify twenty-one conditions that seem necessary for a streamlined PSS design process and an optimal use of frequently applied PSS design tools. These PSS preconditions seem to lead to a better compatibility between the traditional PSS design process and the PSS design tools [40]. The contextualization provided by the experts attribute each precondition to the specific process phase they belong to, and the necessary PSS design tools to address them accordingly. We hereby contribute to the literature of servitization and PSS and enrich the PSS design process per phase both in execution and support.

In this article, firstly, we describe the chosen research methodology and clarify our methods of data collection. Secondly, we translate the typical characteristics of PSS into operational preconditions based on the prior literature. Thirdly, these insights serve as the input for in-depth contextualization, positioning the relevance of the preconditions in relation to the PSS design toolkit. Finally, we present a visually aligned PSS design framework, connecting the preconditions to the toolkit's process and methods. We conclude

with the main theoretical contributions of this study, and make specific recommendations for practice, as well as suggestions for future research.

2. Materials and Methods

2.1. Research Framing Methodology

This research paper uses Research in Design Context (RIDC) as its framing methodology. This type of design research is about developing an understanding and building theory that adds to the disciplinary knowledge of design, in our case related to the phenomenon PSS. This approach for design research in the context of PSS, is appropriate for considering users' involvement in the design process [41].

The problems related to PSS implementation are analyzed through a study of the literature and infused with practice-based interviews, in order to derive process preconditions that strengthen the integrated PSS design process in the Front-End of Innovation. RIDC follows the six-stage process flow model shown in Figure 2 below. The process holds two parts: a first phase of explorative research actions, and a second phase of confirming research actions [42].

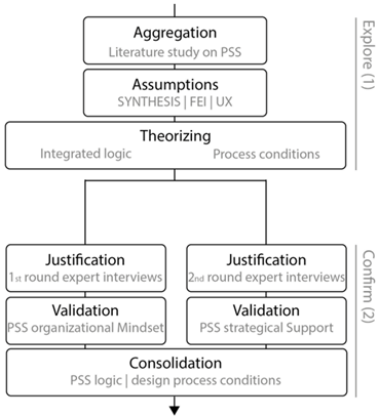

Figure 2. Research in Design Context (RIDC).

2.2. Research Method

This paper combines its research methods for data collection with corresponding techniques of analysis, suitable when research questions tackle relatively new subjects [43]. Using the framing methodology RIDC (Figure 2), we confront the extant literature on PSS, its assumptions and theory with five in-context interviews. The findings from the explorative phase are validated by the confirmative phase, iteratively linking theory and practice in order to obtain enriched relevance [44]. It is not our intention to create new theory, but rather to integrate and extend existing theories on PSS. As such, we examined the literature relevant to the dynamic phenomenon of PSS, and employ the empirical data to fill in the gaps, reveal its flaws, elaborate its meaning, and extend its coverage [44,45]. RIDC is similar to the approach of systematic combining [46], used in the field of industrial marketing that rests on interpretive methodologies and abductive reasoning. Its constant infusion of research findings gathered in subsequent rounds and additional theoretical framing after each round offers more guidance for theory development and allows for managerial recommendations that are highly contextualized [47,48]. This results in more actionable and relevant prescriptions when dealing with complex issues and phenomena that are highly unstructured and still in the context of discovery such as the study of integrated PSS design [49]. The qualitative approach of RIDC is appropriate to consolidate theory and practice and to enrich the findings through contextualization [44]. We conclude that a qualitative, interpretative research methodology seems to offer guidance for in-depth exploration of PSS and theory development.

2.2.1. Literature Review

Our study of the literature serves to unravel the concept of PSS, its adjacent connotations and meanings. With an explorative purpose [50], we initiated our literature review on Web of Science (WoS) with a navigation of the collection of journals [38,51–53], books [36,54–58], and proceedings that have enabled us to describe the synthesis approach for products and services.

In this review, we made use of terminological analysis, chaining and concept mapping, methods introduced by Webster and Watson [59].

The terminological analysis serves as a controlled finding of search terms to spot new emerging concepts and terminology in different directions (e.g., business economics, operations research, marketing, engineering, and product innovation management). The use of broader and narrower terms brought us to a range of phenomena associated with PSS or frequently interchanged with PSS [22,23,32,38,56,60–68]. All of these concepts have vastly contributed to the foundation and our current understanding of PSS as an emerging area and as a phenomenon [69]:

- Functional (total care) product;
- Functional product development;
- Functional sales;
- Functional thinking;
- Hybrid product–service/offering;
- Integrated systems/systems integration;
- Industrial product–service systems (IPS^2);
- Integrated product–service engineering (IPSE);
- Product–service combinations/mixes;
- Product–service integration;
- Service–dominant logic (SD logic);
- Service economy;
- Service engineering;
- Service product;
- Service–product engineering (SPE);
- Servicification;
- Servicizing;
- Servitization;
- Soft products;
- Systemic solutions.

Consecutively, we used a chaining strategy as search technique in order to retrieve the initial projects and research providing elaborated descriptions of the PSS phenomenon in a design context.

Finally, concept mapping enabled us to specify the core terms by separating concepts, organizing synonyms of the core concepts. Besides the more typical sources, we were able to retrieve a lot of information of the fields these terms relate to, such as PhD dissertations [2,70–72], project reports, and briefings [73–76].

In order to further structure and connect these findings in a suited format, we performed a second search on the Web of Science (Table 1). Clearly, PSS is of interest to a diverse range of research areas and subject to cross-fertilization [3,11].

Table 1. Interviewed experts.

Web of Science (WoS) Search Term	No of Publications
"product–service system" as topic	2254
refining with "design" as topic	1226
filter "product–service system" in the title	683
refining with "design" as topic	440
"product–service system" AND "design" in the title	179

Within these 179 remaining publications, we checked whether they provide definitions for PSS. Ultimately, we analyzed forty-six PSS-related definitions, each with its typically sustainable-, economic-, or user-oriented focus. Obviously, these three foci put a different type of emphasis on various priorities and expectations of PSS [77]. However, since sustainability is a possible benefit of a PSS but not a necessary component for the system to be a PSS [78], we omitted the sustainability-oriented characteristics for further analysis. It was less obvious to separate economic and user-oriented definitions as two different goals. As justified by Haase, Pigosso, and McAloone [78], we see a clear convergence regarding these two key characteristics of PSS, integrating product and services, as well as the focus on customer needs, when exploring the archetypical structure of PSS related definitions [37,52,75,79–85]. We continued our search by means of a semantic analysis, looking for characteristics and recurring (key)words within the remaining definitions and its related terminology relevant in the PSS design process, such as value proposition, business model, strategy, network, system, stakeholders, life cycle phases, (non-)technological, value in use, needs, consumer, etc. [2,37,39,52,53,70,73,81,85–96].

The literature review has enabled us to generate a list of process preconditions that support companies to overcome barriers for incorporation a synthesis-driven implementation of PSS design.

2.2.2. In-Depth Expert Interviews

For the in-depth exploration of the central phenomenon of this research, the use of semi-structured in-depth interviews—as qualitative and interrogative research method—was deemed most appropriate. Given the exploratory nature of the study, we needed insights into the cognitive frames of people with specific responsibility, knowledge and experience related to PSS design projects, familiar with the tools and providing the link between design agencies, industry and the academic scene. Consequently, we use purposive sampling. The purpose is not to generate a representative sample and then generalize the results to other contexts, but rather to learn from people who are "information rich" helping to understand different perspectives on the central phenomenon [97] and allowing a holistic analysis, appropriate for PSS. The interviews offer context-rich descriptions, implementation aspects and suggest valuable prescriptions to practitioners [49,98].

Several experts were contacted with a personalized email request for a recorded, face-to-face interview including a short description of the research purpose and central phenomenon to make sure that all chosen respondents would address the issues that are of interest for this study. In order to obtain more detail, we assessed the respondents' knowledge about the scope and facilitation of product–service integration at different business levels. Table 2 shows the five experts we ultimately selected for the in-depth interviews. Closely involved in the design process, these experts have the knowledge of the PSS design and development context in which humans and products/services interact. The contextualization of the PSS practice provides (i) a more specific delineation and purpose of PSS, (ii) the curation of context-related preconditions in which PSS can be investigated, (iii) an identification of the relevant stakeholder relationships, and (iv) the interpretation of data in the given context [41]. The interviews took two to three hours. This allowed us to react and elaborate on emerging ideas. The results could be more easily compared, and this minimized the influence of the researchers' attitudes and previous findings [97,99–101].

Table 2. Interviewed experts.

Expert	Role	Organization and Scope	Country
1	Program manager knowledge transfer	Expertise Center Business Design & Innovation of a business school, stimulating product–service design and innovation	Belgium (Antwerp)
2	Design management coach		

Table 2. *Cont.*

Expert	Role	Organization and Scope	Country
3	Managing partner	Service design agency; design of organizational processes, whole systems, products, services, and purposeful experiences in a complex digital environment	Belgium (Brussels)
4	Lead expert	Competitive Advantage through Strategic Design project—Creative Industry Scientific Program, effective strategic design thinking enhancing the competitive position of PSS	The Netherlands (Delft)
5	Project manager service design and innovation	Service Science Factory (SSF); design and development of new/improved service concepts, complex service systems, and technology-intensive and transformative services	The Netherlands (Maastricht)/Germany (Köln)

In the first part of the interview, we presented the results of the literature review in the form of PSS design preconditions and asked the experts to provide detailed descriptions as to why and where PSS-related design projects experience barriers. The second part of the interview was used to introduce the PSS design toolkit [40], in order to review these preconditions a second time, providing the critical incidents in the usage of the tools and in order to link individual tools to the according preconditions and to detect the added value they could provide with regard to these specific preconditions.

The interviews were audiotaped and transcribed. Subsequently, we analyzed the qualitative data according to Creswell's procedure [97] (i.e., transcribing interviews, reading through the data, generation of relevant themes, interpreting the meaning of the themes, and comparing these findings with the literature), constantly keeping the context-content-process nexus focus central to our interpretation lenses.

2.2.3. The PSS Design Toolkit

Without rejecting the efforts shown in existing PSS design methodologies, we have designed the PSS design toolkit [40]. Although it does include tools mentioned in other sources, it covers a spectrum of tools and methodologies that successfully provide a 360-degree approach to a systematic PSS design process. The PSS design toolkit received the GPRC-quality label, which certifies that its peer review procedure corresponds to the international academic standards and has been positively evaluated. Figure 3 shows the PSS design toolkit's process and proposed tools for each of the phases: understand, explore, and define. Given the representative variety of the tools covered in this toolkit, we deemed it useful for acting as stimulus during our discussion.

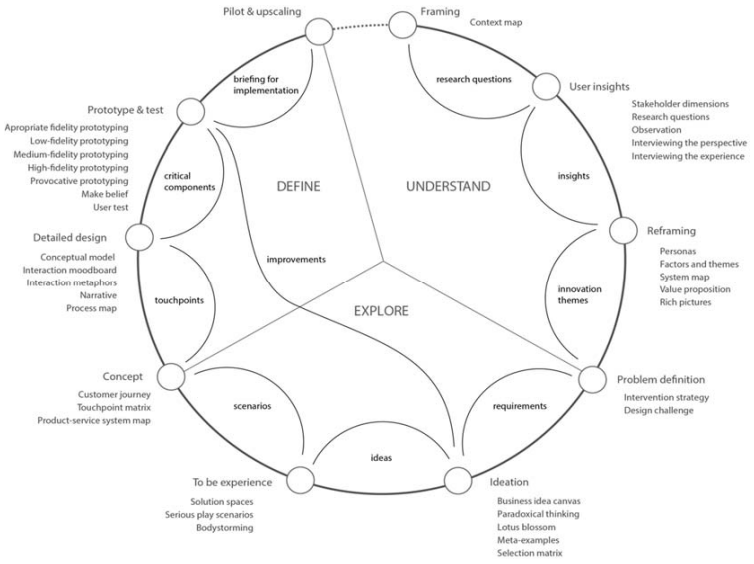

Figure 3. PSS design toolkit overview.

3. Findings and Discussion

In this section, we present the combined findings from our literature review and empirical data from the expert interviews. In a first part we deepen out the concept of PSS and develop an example. In the second part, an overview of the twenty-one preconditions is presented. Thirdly, the practice-related contextualization by the experts, using the PSS design toolkit leads into a discussion on the link between the preconditions and the actual design process. The practitioners' perspective clarifies how the tools help structuring the process and how they address the preconditions relevant at a specific design process stages. For every precondition, the experts provide contextualized descriptions about potential design/application barriers, relevant questions for each step in the process, and the rationale for process-stage specific tools. To understand the goal of the PSS design toolkit, we provide more detailed information on the PSS design tools used in each phase. Finally, a framework aligns the preconditions with frequently used PSS design tools.

3.1. The Delineation and Purpose of Product–Service Integration

In order to understand PSS, Tischner and Vezzoli [37] stress that this field has strong connections to product design and service design and their respective methodologies. Product design, however, has undergone changes during the past decades. Indeed, the design of objects is no longer restricted to form, function, material and production, but focuses on the interaction between people and technology, and products serve as platforms for experiences, functionality and service offerings [102]. Notably over the past decade, the service design also grew in importance. As the customer perspective is even more central to the development of services, companies have been turning to service design methods [4,67,103,104] to better understand the customers' needs and experiences. It has its connection to classical service marketing [32,62] and focuses on the way interactions between the service provider and receiver make a service transaction meaningful. We also see a connection to SD Logic, a philosophical perspective that underpins the innovation-through-services transition and places the user's perspective central in the innovation process [4]. Recently, service design embraced this more holistic approach, perceiving services as "systems consisting of people, artefacts and their interactions" [105]. Consequently, service design plays a crucial part in the integration "into the system" and enables to leap from demarcation to synthesis. Nevertheless, designing PSS is more than just a combination of the former two fields. Research and practice in the domains of product and service innovation are moving toward each other, applying each other's tools and methods due to the complex nature of today's offering, and implying an actual product-service integration. Product-service integration indicates a value proposition that derives its value for a significant part from both the product and service element [73], and the system specifies the mix between products and services [85] and the context. The context can be extended as it describes the raison d'être and core structure of the system, representing the (value) network, (technological) infrastructure and governance structure, even the revenue model that entails a product-service ready for the market [73,77]. The system consequently describes the relations between the stakeholders (ecosystem providing the context), and the interaction with the end-user (affected by the context).

With PSS design, we refer to the process through which a PSS is designed. Without neglecting the benefits of other PSS design tools and methodologies, we use the toolkit developed by Dewit et al. [40]. This eclectic PSS design toolkit combines thirty-six frequently used tools, focusing on three different stages: understand, explore and define.

3.2. PSS Design Process Preconditions

Organizations have developed methodologies and processes to bridge product and service development and boost their value creation. However, this approach implies a different organizational mindset to formalize and establish a vision and strategy for innovation that understands—value and how to integrate products and services. However, despite the fact that more and more companies are actually delivering bundles of product

and service elements [106], there is no coherent picture of how these can be combined during the design process [107,108].

The theory behind PSS and adjacent concepts made it possible to clarify the similarities of products and services (assimilation). However, the literature review also identified a range of differences between products and services on their respective characteristics when it comes to the design, development, process, and methods. Principally, based on what the product is, the service is not (demarcation), and by acknowledging these dis/similarities, the context boundaries and peripheral characteristics of product–service integration become more obvious. Ultimately, simultaneously taking both product and service parts beyond the dichotomy, neglected integrated characteristics of innovation are brought to the surface that are relevant for products, as well as services (synthesis), on a more complex and systemic level.

Justified by a systematic literature review on PSS definitions by Haase, Pigosso and McAloone [78], we elaborate on two key characteristics of PSS, (i) integrating product and services and (ii) the focus on customer needs. A thorough understanding of the PSS concept leads into a set of insights, coined as "preconditions" which are deemed necessary during the PSS design process. The preconditions connect to the relevance of issues raised by Vasantha et al. [38]. These authors claim that methodologies to develop a practical PSS design must be generated. Herein, innovation and added value emerge by considering the following elements: stakeholder requirements, products and services throughout their lifecycle, a process for developing integrated solutions, a good schema for representing PSS concepts, and a comprehensive evaluation of PSS. Eventually, we chose the following six terms to cluster the identified preconditions throughout the PSS design process: "value constellation", "evaluation mindset", "integration", "scenarios", "selection approach", and "product-service system".

We present these twenty-one preconditions in Table 3, listed following the three levels of the process (i.e., understand, explore, and define) in unison with their respective descriptions derived from the literature. Organizations would considerably benefit from a clear set of PSS preconditions that are necessary to support the PSS design process [109]. The type and extent of adoption of these preconditions can positively affect an organization's general disposition toward a product-service transition and seamless integration [23], influencing the resources, capabilities and competences in each of the enabling PSS lifecycle activities [110]. Using the preconditions, companies are also more likely to envision a more holistic notion of user experience [107,108], as opposed to the typical drivers, e.g., market demand, branding considerations, and technological innovations.

Table 3. PSS design process preconditions, structured by phase and cluster.

	Understand: Value Constellation
1	Recognize PSS potential and think more in terms of opportunities of PSS [73].
2	State early "freedom to operate" requirements (IP, contracts ecosystem stakeholders) [73].
3	PSS firms operate in value constellations [111]. The PSS flow is not directly linked to the money flow, it is difficult to compare costs, benefits and economic reward [23,112–114].
4	Experiences do not match the stories if created in isolation from the actual PSS [36]. Allocate means to "execution" (design) opposed to "promise" (marketing) [115,116].
5	Consider broad stakeholder co-creation [31,33,53,73]. Address the multiplicity of needs throughout the whole user experience, essentially in the early stages of design [58,117].
	Understand: Evaluation Mindset
6	Recognize both the differences between product and service design in the development [22] and the strategic linkages between the two areas in the delivery [118].

Table 3. *Cont.*

	Understand: Evaluation Mindset
7	Explicit evaluation and selection criteria [38], besides a trade-off on function and cost of realization [119], include immaterial, non-technological value created by PSS [73].
8	Intangible aspects, user experience [120] set different expectations on product and service [73].
	Explore: Integration
9	Intertwine product and service instead of designing separate elements [31,93,113].
10	Consider product–service interdependencies in the FEI [38,63,93,117].
11	Decide to design the product to meet the service aspects and vice versa [73,93].
12	Recognize differences in the design of products and services [23,63,118,121].
	Explore: Scenarios
13	Co-creation involves different stakeholders in different stages of the PSS design process, according to user centered and service-dominant logic principles [31,33,53,58,73,117].
14	Provide insights in front/back office implications and their lines of visibility [23,113,121–124].
15	Characterize the use phase in PSS, plan or design events, and organize the flow [53,89,125].
16	Align different time frames and generate product and service in interaction with the user [53].
17	Aim for a higher brand execution and design all touchpoints consistent with their promise [115,116].
	Define: Selection Approach
18	Use earlier defined (including intangible) criteria to evaluate/select the PSS concept [73].
19	Show to what extent products and services are mixed and describe the value of each part [73].
	Define: Product–Service System
20	Consider prerequisites for products and services together [23,122], consider the consequences of utilization and possible side-effects [89,125], cater the variables as far as possible [53].
21	Early prototyping provides a means for a better assessment of the outcome, the most appropriate design for a PSS cannot be achieved without iteration [126].

FEI, front-end of innovation.

Practitioners involved in PSS projects can take advantage from looking at the preconditions in Table 3 as a guide to check whether the necessary preconditions are met throughout the design process. The subsequent figures, accompanying tables and contextualized expert descriptions result from a practitioner's perspective.

3.3. The Contextualization of Product–Service Integration

During the in-depth interviews, we have presented the PSS design toolkit overview (Figure 3) as a research instrument, provoking the discussion and as such justifying the list of the twenty-one preconditions with the experts.

Below, we address the three phases in the PSS design process (Figures 4–6), i.e., understand, explore, and define. With a clear connection to Table 3, we integrate the experts' detailed in-context descriptions with the design process and the usage of tools integrating products and services, present at each stage. Taking the preconditions into account, each tool has the potential to unleash its true utility.

3.3.1. PSS Design Process Phase: Understand

As evidenced in Table 4, during the first phase, understand (Figure 4), the design team stepwise comes to an understanding of the system's structure, stakeholders, elements, and their relationships, and they then discover the leverage points that are relevant to rethink the whole system when reframing its purpose. Subsequently, they cluster promising patterns, capture the bigger themes, and ultimately address the underlying situational phenomena. A representation of all insights should encourage stakeholders to discuss, interact and attain a holistic understanding of the PSS's context. Following Table 4, we address

each of the preconditions, contextualized by the experts, and PSS design the tools deemed interesting at that moment.

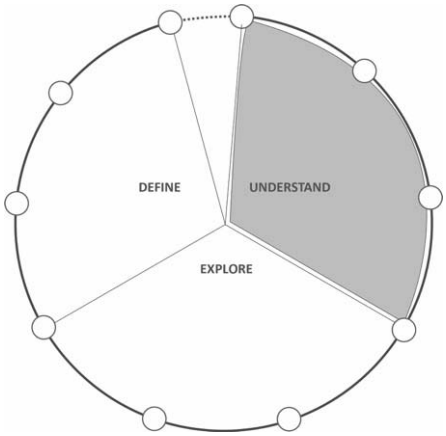

Figure 4. PSS design process phase: Understand.

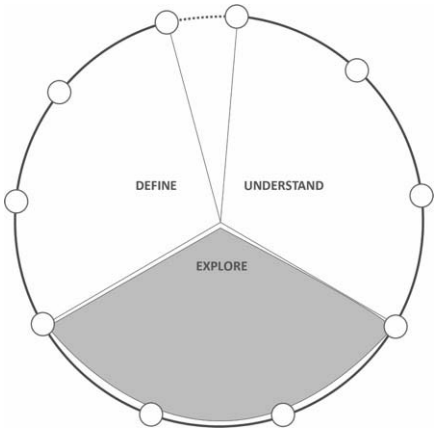

Figure 5. PSS design process phase: Explore.

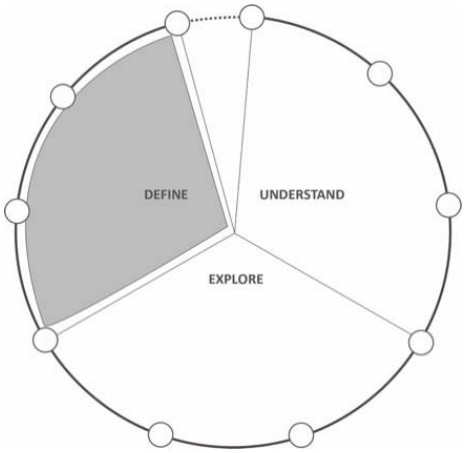

Figure 6. PSS design process phase: Define.

Table 4. PSS design tools and descriptions during the understand phase.

PSS Design Tool	Description and Goal
Context map	Map of context insights (places, products, services, moments of use, goals, and activities).
Stakeholder dimensions	Different perspectives, needs, and expectations of the ecosystem stakeholders and its users.
Research questions	Verification of assumptions and open questions about the unknowns.
Observation	Identify opportunities for improvement, use patterns, hurdles, and unintended behavior.
Interviewing the perspective	Capture the worldview of stakeholder toward the problematic situation.
Interviewing the experience	Find patterns and underlying drives about the current experience and verify assumptions.
Personas	Communicate all prior user insights and use them to verify solutions from these perspectives.
Factors and themes	Explore field research factors, find patterns (human drives) and themes behind them.
System map	Discover leverage points in the complex system and relationships between variables.
Value proposition	Economic, psychological, sociological, and ecological value for people, ecosystem, and society.
Rich pictures	Holistic representation and understanding of the issue, encourage discussion.
Intervention strategy	discuss feasibility/leverage with stakeholders (on which levels) to intervene.
Design challenge	Problem and requirements (context, interaction, service, product, rational, and emotional).

The tools that support the PSS design process in this phase (Table 4) are only effective to the extent in which Preconditions 1–8 are catered for. Below, the experts provide the recognizable circumstances and give detailed descriptions about the typical project barriers for each of the preconditions relevant for the first phase in the PSS design process, understand:

1. Recognizing the economic potential of PSS comes from a clear understanding of the concept and context itself (corresponding tools: context map, research questions, observation, interviewing the perspective, and interviewing the experience). PSS design creates value for people, the ecosystem and society. Value residing in both product and service and its systematic design approach to bridge the knowledge gap companies might experience [8].
2. Experts assert that at the beginning of a project, it is hard to know the real advantages of the PSS and the value's origin. Services, interactions, and experiences are hard to patent, but influence continuous growth and innovation of the ecosystem, inherent and essential to keep the PSS alive. So, what is in it for all parties involved to buy-in? (corresponding tool: value proposition).
3. The evolving nature of PSS value makes long-term thinking indispensable. Experts bring two arguments to the table to clarify Precondition 3 in terms of integration readiness [4,16,17]. The first is the *capital-intensive* argument and depends on the engagement and profit sharing among actors participating in the development and provision of the PSS. Not every company considers shutting down their primary source of income in favor of secondary sources of income like renting, sharing, or pay-per-use. The second argument is more *culturally driven* and deals with the degree of innovativeness and risk taking. A shift in ownership has consequences for the user's relationship with the PSS (e.g., exposure, availability, knowledge, asset management, tracking, etc.), making customer value more about the perceived experience (corresponding tools: stakeholder dimensions and persona).
4. With regard to Precondition 4, experts argue that smaller companies are closer to the customer and therefore more easily prepared to allocate resources differently. For larger companies, (re)allocation is rather structurally embedded, which has a rather sales-driven, short-term effect on business (e.g., incentives policy, sell more of what sells well, and competitor-driven), but often this market pull situation tends to dictate R&D [127]. Blurring boundaries between marketing and design are favorable to the long-term user lock-in, overcoming the sales-driven short-term approach [11] (corresponding tool: value proposition).
5. In PSS design, "co-exploration" requires stakeholder involvement. Improving aspects of someone's life (ensuring value delivery), one must keep focus on the user experience (corresponding tools: stakeholder dimensions and persona tool). Stakeholder alignment from the beginning, participatory conceptualization and a shared vision or metaphor are essential (corresponding tools: system map and rich picture).

6. Products are easier to compare but opposed to product development efficiency, the "raison d'être" for services is still at risk. For Precondition 6, experts suggest using milestones instead of making Go/No Go decisions, because services are more iterative, require different lenses and frequent intermediate checks to enable faster and constant user testing (e.g., hiring five employees with a specific profile toward customer friendliness, opposed to the cost for an injection molding prototype) (corresponding tools: rich picture and intervention strategy).
7. In order to overcome evaluation difficulties, our experts provided insights on the criteria for a more formalized evaluation process: (1) criteria derived from the business strategy, e.g., financial, logistical, distribution, and organizational; (2) criteria linked to the project feasibility, e.g., how far reach resources like time, budget, machinery, and employees; (3) criteria recurrent for each project, e.g., remaining gap to the actual proposition; (4) criteria formulated throughout the process in parallel with the concept development; and (5) recurrent user testing (corresponding tools: intervention strategy, and design challenge).
8. After an ideation process, good ideas might be incompatible with traditional criteria. However, due to a need for integrated solutions, it is important to include them, to be flexible and to be open to new ways for evaluation. The actual calculations should be performed after the ideas roll out. For PSS, the real differentiator for impact might be provided by the service side (corresponding tool: design challenge).

3.3.2. PSS Design Process Phase: Explore

The preconditions presented in Table 3 align with the methods to the PSS design process in Table 5 below. Throughout the second phase, explore (Figure 5), the design challenge and diverse stakeholder requirements set ground for explorative purposes. The design team initiates an idea generation process on (in)tangible system–user interactions and creates solution spaces for the system and its constituting parts, focusing on both front- and backstage user interactions, the physical location and the artefacts used. PSS scenarios help to assess operational validity and added value with stakeholders. The experts contextualize each of the preconditions, following Table 5.

Table 5. PSS design tools and descriptions during the explore phase.

PSS Design Tool	Description and Goal
Business ideation canvas	Incorporate business model thinking during ideation and extend to IoT [1] possibilities.
Paradoxical thinking	Achieve solutions for the whole, by generating unusual viewpoints of the problem.
Lotus blossom	Look for solutions in existing systems or how other disciplines fulfil the requirements.
Meta-examples	Use metaphors in unfamiliar design problems and find solutions in known situations.
Selection matrix	Select ideas based on value for the users and operational validity for the company.
Solution spaces	Juxtaposing exploration leads to a range of scenarios and related business concepts.
Serious play scenarios	Think from a user's standpoint and go through all the steps of the future experience.
Body storming	Immersive understanding of interaction between people, context, product, and service.
Customer journey	User/stakeholder view on touchpoints, front-/backstage interaction, and support processes.
Touchpoint matrix	Visual system–user connections with multi-channel, cross-device platforms, and services.
Product–service system map	Discuss or validate the visual representation of the future PSS with stakeholders.

[1] Internet of Things, incorporating the possibilities for the generated (meta)data.

Similar as in the understand phase, the tools that support the PSS design process in this explore phase (Table 5) are only effective to the extent that Preconditions 9–17 (Table 3) are considered. The following paragraphs contextualize the preconditions and tools regarding the second phase of the PSS design process.

9. There are several (path)ways that companies can take in designing PSS, affecting the type of integration [7]. Quite often, companies add a service to existing product or vice versa in a sequential manner, but when product and service meet at the first user test, it is too late. Experts emphasize that both disciplines (product and service)

should match their work in parallel and iterate as often as possible, resulting in a continuous process of diverging and converging actions and cooperation toward mutual milestones to check project performance and progress (corresponding tools: solution spaces).

10. During the project's strategic planning, the experts emphasize that it is important for stakeholders to articulate how far they want to engage with respect to the product or service part in the PSS. This brings clarity of involvement throughout the project and enables product-service modularity (corresponding tool: selection matrix and related discussion on operational validity).
11. In multiple projects, experts notice that the service must adapt to the product in the later development stages because of cost considerations. A nested view forces product and service to adapt to each other and enables an essential divergence of ideas and convergence into an integrated product-service concept (corresponding tools: business ideation canvas, paradoxical thinking, and solution spaces).
12. The importance is stressed for companies to consider the same metrics (in terms of equality) for services and products, to know to what extent the products or services are responsible for the actual value. Only then, the company can really optimize product-service combinations. Customers observe PSS as a combined solution and return feedback in terms of an integrated experience (corresponding tool: selection matrix).
13. Companies' belief in "co-creation" in its pure form has strongly diminished. Although a wide involvement of stakeholders is encouraged as from day one, experts argue that terminologically, it is better to refer to it as "cogeneration" in the ideation phase (corresponding tools: lotus blossom and meta-examples). More importantly, the PSS process requires a steering committee to ensure recurrent user testing is coordinated and acceptance levels are guaranteed.
14. Experts agree that evidencing is an important aspect of the "explore" phase, because of the implications for front- and backstage. Either the context, another user, or an employee makes the connection and defines the interaction with the product and service. Companies taking this into account usually postpone their judgement (on feasibility, costs and implementation implications) until the product-service concept has been tested and accepted by the user (corresponding tool: customer journey).
15. Focusing on the user experience as early in the process as possible, enables an early characterization of the use phase as well. Even without a full solution, it reveals the opportunities or flaws in every touchpoint throughout the PSS user journey. Visualization and (early) prototypes help overcome the language barriers to understand these flaws and opportunities (corresponding tools: customer journey and serious play scenarios).
16. Experts address the importance of continuous feedback loops in the design process. All aspects of the PSS concept should be able to trigger conversation and early customer feedback (corresponding tool: body storming). Think in terms of time (long term), touchpoints and new customs throughout the customer journey.
17. If one strives for a consistent brand promise, experts emphasize that companies should convey this brand identity through every touchpoint as early as possible to increase credibility (corresponding tools: PSS map and touchpoint matrix). It is important to leave room for improvement when expectation levels go up, growing from value-in-exchange toward value-in-use and long-term customer relations (e.g., user–system interaction through the multiple touchpoints in pre-, core-, and post-experience).

3.3.3. PSS Design Process Phase: Define

The preconditions presented in Table 3 align with the methods to the PSS design process in Table 6 below. In the third phase, define (Figure 6), the design process bridges the gap between the existing knowledge and the target knowledge of the user (what one has in mind about the product/service, which parts should be understood by whom) through actual design representations. These visual compositions give an identity to novel

or unfamiliar system functionalities and an entrance point for prototyping the system components and the related front- and backstage activities. This defines responsibilities and benefits for all stakeholders and verifies the users' interest in the final solution.

Table 6. PSS design tools and descriptions during the define phase.

PSS Design Tool	Description and Goal
Conceptual model	Assist users to build a mental model of how the system works/how to interact with it.
Interaction mood board	Inspire prototyping with a consistent look and feel over all touchpoints.
Interaction metaphors	Turn a novel interaction (system functionality) into an intuitive, comprehensible one.
Narrative	Present a story of connected events to the stakeholders/end-users for feedback.
Process map	Flowchart of activities needed to deliver the product–service, related business point of view.
Appropriate fidelity prototyping	The goal of the prototype at this stage is to understand a concept's core functionality.
Low-fidelity prototyping	Rough models of the touchpoints, to test solutions fast at low cost.
Medium-fidelity prototyping	The system is defined but search for the optimal functionalities and interactions.
High-fidelity prototyping	Close enough to a final product to be able to examine usability questions in detail.
Provocative prototyping	Deliberately make prototypes to trigger reactions on less straightforward topics.
Make believe	Act out to validate that it really works (prototypes as learning material, not as end-result).
User test	What you want to test with whom, in a realistic test setting; improve your concept.

Like the two prior phases, the tools that support the PSS design process in the define phase (Table 6) only serves its purpose when Preconditions 18–21 (Table 3) are considered. Below, the experts provide in-context descriptions for these preconditions.

18. Continuous discussion and convergence during the previous two phases provide the entrance point to the third phase, leading to an evaluation and selection using appropriate filters and converging to a final solution. During this process, experts advise companies to reconsider the criteria from Precondition 7 and make the criteria objective and measurable and to define the integral character of the system and its constituting parts (corresponding tool: after formulation of the PSS solution and the matching touchpoints, description of the PSS characteristics using the interaction mood board).
19. The experts deemed it interesting for companies to know when to evaluate or benchmark the system and provide possibilities for PSS modularity, the relative importance of the product/service part (corresponding tool: interaction metaphor tool). PSS requires a genuine narrative to overcome the distributed offering and the shift of ownership (corresponding tool: narrative).
20. The experts point out that the distribution of PSS components over product or service affects the design to a large extent. The process should take these side effects into account (corresponding tool: process map). Furthermore, as the PSS evolves over time, end-users will gradually become accustomed to standards. As a result, expectancy levels will go up. When designing PSS, one can already plan for additions or modification later.
21. Commonly agreed upon by our experts, early prototypes provide early customer feedback (corresponding tools: conceptual model, narratives, and process maps). The design process should always bring something tangible to the table, to facilitate the discussion (corresponding tools: make belief and appropriate fidelity prototyping). A PSS can be launched open-ended into the market, testing parts, or the scenario, enabling the customers to lock-in early and refine and reconfigure the product and/or service part (corresponding tools: provocative fidelity prototyping and user test). The prototype allows for testing the intended delivery of user experience value, essential in times of growing standards and expectancy levels (corresponding tools: low-, medium-, and high-fidelity prototyping).

3.4. The PSS Design Framework

The research reveals that practitioners do not seem to have a consistent terminology regarding product–service integration. Rather they adapt their terminology according

to the project or person faced. The choice of terminology related to PSS is dependent on "who" you talk to and the respective connotation they put on the former or the latter component in the system, i.e., product or service. The PSS design framework (Figure 7) proposes a unified terminology and design process for a synthesis approach and integrates the operation sequence and usage of tools combining them with relevant preconditions at each stage.

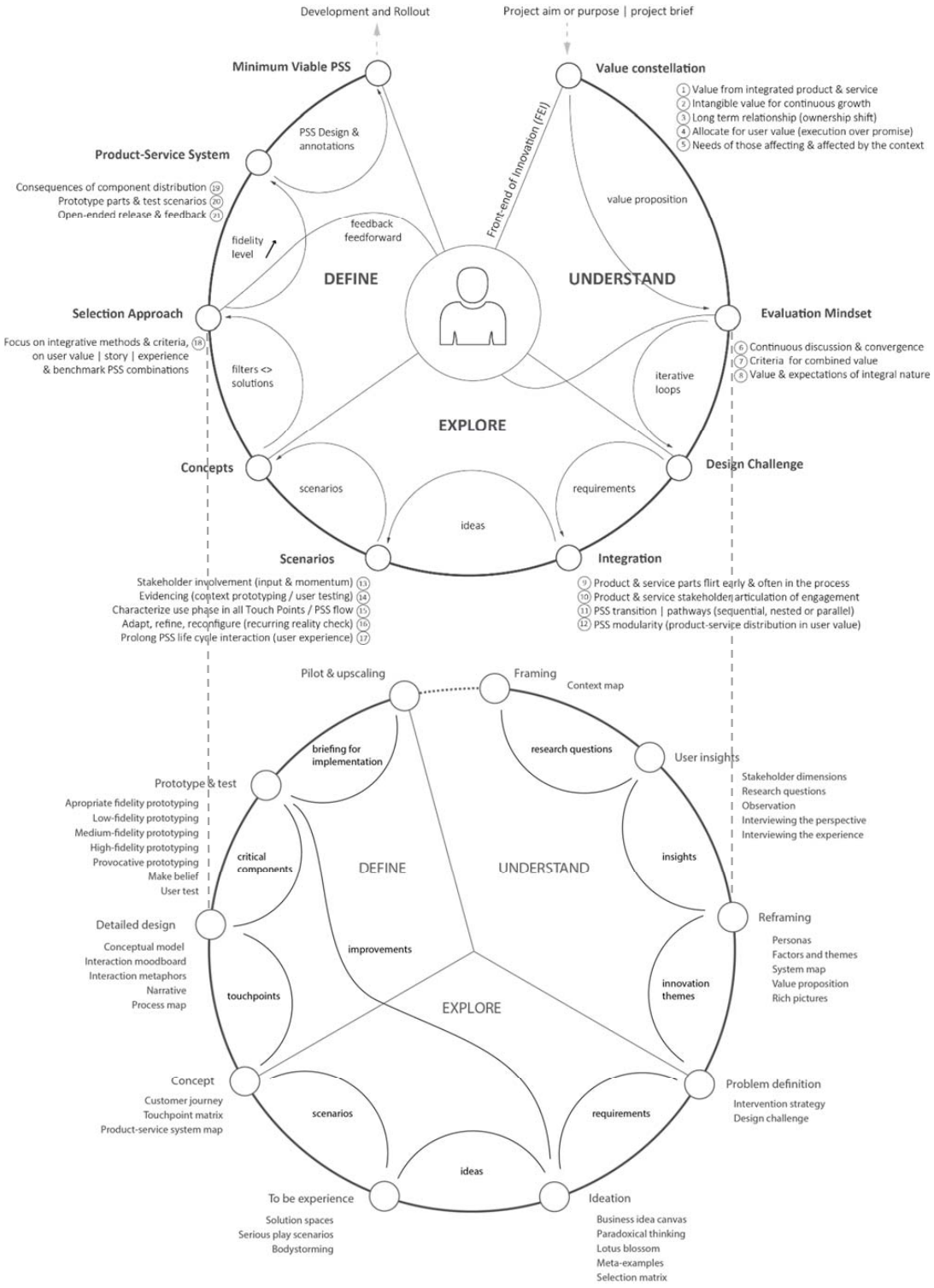

Figure 7. PSS design framework.

The preconditions stress the importance of integration of all relevant aspects as from the beginning in the project and throughout every phase of the innovation process. The focus on the user experience, the balanced integration of both product and service, the permanent focus on value from all perspectives and the constant interaction with stakeholders and end-users throughout the project are the most important. We also stress the importance of frequent iteration between conception and validation in the different phases and adequate criteria for assessment for the integrated components of the combined value carriers.

The input of the process starts with the project brief and ends with the minimum viable PSS as output, ready for development and rollout. During this design process, the management supporting the design team stepwise takes the preconditions into account, listed on the outside of the circle. Clusters derived from the literature review, cluster the preconditions (e.g., value constellation holds the five first preconditions). On the inside of the circle, these clusters fall under the three big phases of the FEI: understand, explore and define. The user is presented at the absolute centre of the process, providing regular feedback and continuously improve the PSS design concept.

The PSS design framework integrates and immediately aligns with the PSS design toolkit overview in the lower part of Figure 7, connecting the preconditions explicitly to each phase as well as suggesting a set of tools addressing them optimally.

Ultimately, this PSS design framework summarizes the paper and visually portrays a systematic approach to product–service integration. We have incorporated the principles of the demarcation approach and distinctively recognize the integration of the service part in PSS. By doing so, more human interaction and emotion comes into play between people, beyond user friendliness or usability. In short, when integrating services with the tangible component [128], the user's perspective and experience become a focal point in integral PSS driven innovation. Applying the synthesis approach, pushes forward the product–service integration in more complex settings. In pursuit of "integration", the system and all stakeholders come into play: the one(s) providing/affecting the context (the ecosystem) and those affected by it (the end-user) and his/her resulting experience in interaction with the system's components. Applying this integration in the front-end of innovation will impact both the product and service parts in the proposed offering. The experts have provided detailed in-context descriptions for each precondition, relevant at a specific moment and when met, resulting in a more efficient the PSS design process and usage of its tools.

4. Conclusions

We present both theoretical and operational connections between the PSS design process, its preconditions, and the tools used, in the form of propositions:

Proposition 1. *The PSS design framework provides a systematic approach to design a PSS in the FEI, integrating product and service from the user's perspective.*

Proposition 2. *The output of the PSS design tools should be able to find a fertilized field. To prepare that field, companies must understand, accept and learn about the value of product–service integration to overcome the PSS "logic" barrier.*

Proposition 3. *The PSS design toolkit stimulates the preconditions and support companies to overcome the PSS "design" barrier and develop fully-integrated PSS.*

Proposition 4. *The categories of tools organized in the PSS design toolkit only serve their purpose optimally if there is a resorptive capacity. The preconditions serve as receptors, enabling the absorption of insights coming from the tools.*

Proposition 5. *Taking the preconditions into account, each PSS design tool has the potential to unleash its true utility, making the PSS design process more effective and reaching the minimum viable PSS more efficiently.*

4.1. Contributions of the Study

In this paper we systematically combine theory and practice, and develop an insight on how to increase an organization's capacity and mindset to develop fully-integrated product-services. Respectively, we have contextualized how barriers in the PSS design processes can be lowered, and how design tools used can become more effective throughout the different design stages, thereby bridging product and service features.

With this article, we contribute to the field of PSS. More specifically, by making explicit the twenty-one preconditions for the three phases in the PSS design process, we have satisfied the demand of Vasantha et al. [38]. We address (i) the involvement of stakeholders throughout the design process and their requirements, (ii) an understanding of the differences and influences of products and services, (iii) a process and (iv) representation schema for developing integrated solutions, and (v) integrate a way to evaluate the PSS design process. Supported by our empirical findings and experience of the experts in interacting with projects in a PSS context, we enrich the design process per phase in both execution and support. As such, we provide a clear connection between the design preconditions for product-service integration, the design process, the tools, and their impact on the result.

As to the managerial contributions of this paper, we pay specific attention to its relevance for practitioners and design teams in the field. For each phase in the design process, the experts describe the preconditions relevant at that moment. Additionally, for each precondition, contextualized descriptions and examples assist managers in a more focused support of design teams and the tools they use throughout the design process. Summarizing the twenty-one preconditions and the PSS design toolkit in one visual overview ultimately operationalizes the preconditions and stimulates the usage of corresponding PSS design tools, making the PSS design process more efficient.

4.2. Limitations of the Study

A focus on the FEI, user centricity, and synthesis limit the scope of this study.

Using a purposeful sampling strategy for the expert-interviews, the subjects in this small (five) nonprobability sample were selected based on their accessibility and purposive personal judgment. Therefore, this study might seem limited by its five respondents, though we emphasize that our purpose is not to generate a representative sample, nor to generalize the results to other contexts, but rather to learn different perspectives on the incorporation and implementation of PSS. We did not highlight individual background or original/specific domain knowledge the interviewees stem from, because we focus on a synthesis approach. The results were presented as joint findings, focusing on product–service integration.

Obviously, there are general limitations with respect to the fields of application.

The study affects all suggested contexts, but when we talk about the end-user, we mostly consider B2C organizations with a product-oriented tradition.

We have concentrated on the delivery of value to the customer as the distinguishing factor to provide support for product–service integration. Nevertheless, it is worth mentioning (but out of the scope of this paper) that sustainability and digitization are inevitably related with the design of product–service systems. We also did not address companies' barriers related to development or rollout, and we are aware that also other factors, e.g., the institutional context, the strategic implementation, and change management approach, must be taken into consideration as well.

4.3. Future Research

We could learn considerably from practitioners and people in academia implementing and testing the PSS design preconditions in a realistic setting, separately or in relation to our PSS design toolkit. It would be especially interesting to see how our PSS design tools compare to other sets of tools that address product–service integration.

Obviously, there are many other company-specific constraints set as additional boundaries to the implementation of PSS design, putting pressure on the preconditions and the discussed PSS design tools. We would need to investigate into the next level of PSS design toolkit implementation, beyond the "normative" map and into the "real world" territory.

Finally, we want to further investigate how our PSS design preconditions and toolkit can complement and build on the existing knowledge of sustainable PSS. Should we integrate and verify PSS design preconditions and related tools with the sustainability perspective? Moreover, as such, can our framework enable sustainable PSS design to better reach their goals, using the user perspective to aspire current and future sustainable goals?

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References

1. Kiel, D.; Arnold, C.; Voigt, K.I. The influence of the Industrial Internet of Things on business models of established manufacturing companies—A business level perspective. *Technovation* **2017**, *64*, 4–19. [CrossRef]
2. Ceschin, F. The Introduction and Scaling up of Sustainable Product-Service Systems A New Role for Strategic Design for Sustainability. Ph.D. Thesis, Politecnico di Milano, Milan, Italy, 2012.
3. Boehm, M.; Thomas, O. Looking beyond the rim of one's teacup: A multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. *J. Clean. Prod.* **2013**, *51*, 245–260. [CrossRef]
4. Costa, N.; Patrício, L.; Morelli, N.; Magee, C.L. Bringing Service Design to manufacturing companies: Integrating PSS and Service Design approaches. *Des. Stud.* **2018**, *55*, 112–145. [CrossRef]
5. Bertoni, A.; Bertoni, M.; Panarotto, M.; Johansson, C.; Larsson, T.C. Value-driven product service systems development: Methods and industrial applications. *CIRP J. Manuf. Sci. Technol.* **2016**, *15*, 42–55. [CrossRef]
6. Coreynen, W.; Matthyssens, P.; De Rijck, R.; Dewit, I. Internal levers for servitization: How product-oriented manufacturers can upscale product-service systems. *Int. J. Prod. Res.* **2017**, *56*, 2184–2198. [CrossRef]
7. Dewit, I.; Matthyssens, P. A prelude for PSS. In *Conference Proceedings of the Academy for Design Innovation Management*; Academy for Design Innovation Management: Hong Kong, China, 2019; Volume 1, pp. 491–504.
8. Parida, V.; Sjödin, D.R.; Wincent, J.; Kohtamäki, M. Mastering the transition to product-service provision: Insights into business models, Learning activities, and capabilities. *Res. Technol. Manag.* **2014**, *57*, 44–52. [CrossRef]
9. Kim, Y.S. A representation framework of product-service systems. *Des. Sci.* **2020**, *6*. [CrossRef]
10. Sassanelli, C.; Pezzotta, G.; Pirola, F.; Rossi, M.; Terzi, S. The PSS design GuRu methodology: Guidelines and rules generation to enhance PSS detailed design. *J. Des. Res.* **2019**, *17*. [CrossRef]
11. Brambila-Macias, S.A.; Sakao, T.; Kowalkowski, C. Bridging the gap between engineering design and marketing: Insights for research and practice in product/service system design. *Des. Sci.* **2018**, *4*, e7. [CrossRef]
12. West, S.; Di Nardo, S. Creating Product-service System Opportunities for Small and Medium Size Firms Using Service Design Tools. *Procedia CIRP* **2016**, *47*, 96–101. [CrossRef]
13. Sassanelli, C.; Pezzotta, G.; Sala, R.; Correia, A.; Terzi, S. Testing the Methodology to Generate Design for Product Service Supportability (DfPSS) Guidelines and Rules: An Application Case. *Procedia CIRP* **2017**, *64*, 265–270. [CrossRef]
14. Rondini, A.; Pezzotta, G.; Pirola, F.; Rossi, M.; Pina, P. How to Design and Evaluate Early PSS Concepts: The Product Service Concept Tree. *Procedia CIRP* **2016**, *50*, 366–371. [CrossRef]
15. Mourtzis, D.; Fotia, S.; Doukas, M. Performance indicators for the evaluation of product-service systems design: A review. In *IFIP Advances in Information and Communication Technology*; Springer: Cham, Switzerland, 2015; Volume 460, pp. 592–601.

16. Coreynen, W.; Matthyssens, P.; Gebauer, H. Are you ready for servitization? A tool to measure servitization capacity. In *Practices and Tools for Servitization: Managing Service Transition*; Palgrave Macmillan: Cham, Switzerland, 2018; pp. 25–39, ISBN 9783319765174.
17. Teso, G.; Walters, A. Assessing Manufacturing SMEs' Readiness to Implement Service Design. *Procedia CIRP* **2016**, *47*, 90–95. [CrossRef]
18. Ryan, L. Facilitating the Transition from Product-Orientated to Product Service Systems. In Proceedings of the 2nd Cambridge Academic Design Management Conference, 4–5 September 2013; University of Cambridge: Cambridge, UK, 2013; pp. 1–14.
19. Witell, L.; Snyder, H.; Gustafsson, A.; Fombelle, P.; Kristensson, P. Defining service innovation: A review and synthesis. *J. Bus. Res.* **2016**, *69*, 2863–2872. [CrossRef]
20. Morrar, R. Innovation in Services: A Literature Review. *Technol. Innov. Manag. Rev.* **2014**, *4*, 6–14. [CrossRef]
21. Djellal, F.; Gallouj, F.; Miles, I. Two decades of research on innovation in services: Which place for public services? *Struct. Chang. Econ. Dyn.* **2013**, *27*, 98–117. [CrossRef]
22. Meier, H.; Roy, R.; Seliger, G. Industrial Product-Service systems-IPS2. *CIRP Ann. Manuf. Technol.* **2010**, *59*, 607–627. [CrossRef]
23. Nijssen, E.J.; Hillebrand, B.; Vermeulen, P.A.M.; Kemp, R.G.M. Exploring product and service innovation similarities and differences. *Int. J. Res. Mark.* **2006**, *23*, 241–251. [CrossRef]
24. de Brentani, U. Success Factors in Developing New Business Services. *Eur. J. Mark.* **1991**, *25*, 33–59. [CrossRef]
25. Scheuing, E.E.; Johnson, E.M. A Proposed Model for New Service Development. *J. Serv. Mark.* **1989**, *3*, 25–34. [CrossRef]
26. Barquet, A.P.B.; de Oliveira, M.G.; Amigo, C.R.; Cunha, V.P.; Rozenfeld, H. Employing the business model concept to support the adoption of product-service systems (PSS). *Ind. Mark. Manag.* **2013**, *42*, 693–704. [CrossRef]
27. Secomandi, F.; Snelders, D. The Object of Service Design. *Des. Issues* **2011**, *27*, 20–34. [CrossRef]
28. Lovelock, C.; Gummesson, E. Whither services marketing?: In search of a new paradigm and fresh perspectives. *J. Serv. Res.* **2004**, *7*, 20–41. [CrossRef]
29. Vargo, S.L.; Lusch, R.F. The Four Service Marketing Myths: Remnants of a Goods-Based, Manufacturing Model. *J. Serv. Res.* **2004**, *6*, 324–335. [CrossRef]
30. Trott, P. *Innovation Management and New Product Development*, 5th ed.; Pearson Education Limited: London, UK, 2011; ISBN 9780273736561.
31. De Bont, C.; Brombacher, A.; Eggenkamp, M.; Poelman, W.; Hoorn, J.; Berendsen, M.; Jansen, E.; Eggen, B.; Hekkert, P.; Gemser, G.; et al. *Creative Industry Research Programme (CIRP) Design of Product Service Systems and Transformations in Experience*; Delft University of Technology: Delft, The Netherlands, 2009; pp. 1–86.
32. Vargo, S.L.; Lusch, R.F. Evolving to a New Dominant Logic for Marketing. *J. Mark.* **2004**, *68*, 1–17. [CrossRef]
33. Drejer, I. Identifying innovation in surveys of services: A Schumpeterian perspective. *Res. Policy* **2004**, *33*, 551–562. [CrossRef]
34. Langerak, F.; Hultink, E.J.; Henrys, J. The role of predevelopment activities in the relationship between market orientation and performance. *R&D Manag.* **2004**, *34*, 295–309. [CrossRef]
35. Reid, S.E.; De Brentani, U. The fuzzy front end of new product development for discontinuous innovations: A theoretical model. *J. Prod. Innov. Manag.* **2004**, *21*, 170–184. [CrossRef]
36. Merholz, P.; Wilkens, T.; Schauer, B.; Verba, D. *Subject to Change: Creating Great Products and Services for an Uncertain World*; O'Reilly Media, Inc.: Newton, MA, USA, 2008; ISBN 9780596516833.
37. Tischner, U.; Vezzoli, C. Design for Sustainability (D4S): A Step-By-Step Approach. Available online: http://www.d4s-sbs.org/d4s_sbs_manual_site.pdf (accessed on 12 April 2021).
38. Vasantha, G.V.A.; Roy, R.; Lelah, A.; Brissaud, D. A review of product-service systems design methodologies. *J. Eng. Des.* **2012**, *23*, 635–659. [CrossRef]
39. Baines, T.; Lightfoot, H.; Evans, S.; Neely, A.; Greenough, R.; Peppard, J.; Roy, R.; Shehab, E.; Braganza, A.; Tiwari, A.; et al. State of the art in product-service systems. *J. Eng. Manuf.* **2007**, *221*, 1543–1552. [CrossRef]
40. Dewit, I.; Van Ael, K.; De Roeck, D.; Baelus, C.; De Rijck, R.; Coreynen, W. *PSS Design and Strategic Rollout: Tools for Product-Service Systems*; Dewit, I., Ed.; University Press Antwerp (UPA): Antwerp, Belgium, 2018; ISBN 9789057186608.
41. Horváth, I. Comparison of three methodological approaches of design research. In Proceedings of the ICED 2007, the 16th International Conference on Engineering Design, Paris, France, 28–31 July 2007.
42. Horváth, I. Differences between "research in design context" and "design inclusive research" in the domain of industrial design engineering. *J. Des. Res.* **2008**, *7*, 61–83. [CrossRef]
43. Currall, S.; Towler, A. Research Methods in Management and Organizational Research: Toward Integration of Qualitative and Quantitative Techniques. In *Handbook of Mixed Methods in Social & Behavioral Research*; Tashakkori, A., Teddlie, C., Eds.; Sage: Thousand Oaks, CA, USA, 2003; pp. 513–526. ISBN 0761920730.
44. Matthyssens, P.; Vandenbempt, K. Cognition-in-context: Reorienting research in business market strategy. *J. Bus. Ind. Mark.* **2003**, *18*, 595–606. [CrossRef]
45. Danneels, E. The dynamics of product innovation and firm competences. *Strateg. Manag. J.* **2002**, *23*, 1095–1121. [CrossRef]
46. Dubois, A.; Gadde, L.E. Systematic combining: An abductive approach to case research. *J. Bus. Res.* **2002**, *55*, 553–560. [CrossRef]
47. Dubois, A.; Gadde, L.E. "Systematic combining"—A decade later. *J. Bus. Res.* **2014**. [CrossRef]
48. Orton, J.D. From inductive to iterative grounded theory: Zipping the gap between process theory and process data. *Scand. J. Manag.* **1997**, *13*, 419–438. [CrossRef]

49. Hunt, S.D. *Foundations of Marketing Theory: Toward a General Theory of Marketing*; M.E. Sharpe: London, UK, 2002; ISBN 978-0765609298.
50. Hart, C. *Doing a Literature Review: Releasing the Social Science Research Imagination*, 1st ed.; Sage: London, UK, 1998.
51. Neris, V.P.A.; Baranauskas, M.C.C. A framework for designing flexible systems. In Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Anchorage, AK, USA, 9–12 October 2011; Volume 95, pp. 2600–2607.
52. Manzini, E.; Vezzoli, C. A strategic design approach to develop sustainable product service systems: Examples taken from the "environmentally friendly innovation" Italian prize. *J. Clean. Prod.* **2003**, *11*, 851–857. [CrossRef]
53. Morelli, N. Designing Product/Service Systems: A Methodological Exploration. *Des. Issues* **2002**, *18*, 3–17. [CrossRef]
54. Birkhofer, H. *The Future of Design Methodology*; Birkhofer, H., Ed.; Springer: London, UK, 2011; ISBN 978-0-85729-615-3.
55. den Ouden, E. *Innovation Design: Creating Value for People, Organizations and Society*; Springer: London, UK, 2012; ISBN 9788578110796.
56. Hesselbach, J.; Herrmann, C. *Functional Thinking for Value Creation*; Springer: Heidelberg, Germany, 2011.
57. Sakao, T.; Lindahl, M. *Introduction to Product/Service-System Design*; Springer: London, UK, 2009; ISBN 9781848829084.
58. Van Halen, C.; Vezzoli, C.; Wimmer, R. *Methodology for Product Service System Innovation: How to Develop Clean Clever and Competitive Strategies in Companies*; Royal Van Gorcum: Assen, The Netherlands, 2005; ISBN 9023241436.
59. Webster, J.; Watson, R.T. Analyzing the Past to Prepare for the Future: Writing a Literature Review. *Manag. Inf. Syst.* **2016**, *26*.
60. Maussang, N.; Zwolinski, P.; Brissaud, D. Evaluation of Product-Service Systems During Early Design Phase. In *Manufacturing Systems and Technologies for the New Frontier*; Springer: London, UK, 2008; pp. 547–552, ISBN 978-1-84800-266-1.
61. Sakao, T.; Panshef, V.; Dörsam, E. Addressing uncertainty of PSS for value-chain oriented service development. In *Introduction to Product/Service-System Design*; Springer: London, UK, 2009; pp. 137–157, ISBN 9781848829084.
62. Vargo, S.L.; Lusch, R.F. Service-dominant logic: Continuing the evolution. *J. Acad. Mark. Sci.* **2008**, *36*, 1–10. [CrossRef]
63. Kowalkowski, C. What does a service-dominant logic really mean for manufacturing firms? *CIRP J. Manuf. Sci. Technol.* **2010**, *3*, 285–292. [CrossRef]
64. Akaka, M.A.; Vargo, S.L. Extending the context of service: From encounters to ecosystems. *J. Serv. Mark.* **2015**, *29*, 453–462. [CrossRef]
65. Chandler, J.D.; Lusch, R.F. Service Systems: A Broadened Framework and Research Agenda on Value Propositions, Engagement, and Service Experience. *J. Serv. Res.* **2015**, *18*, 6–22. [CrossRef]
66. Matthyssens, P.; Vandenbempt, K. Service addition as business market strategy: Identification of transition trajectories. *J. Serv. Manag.* **2010**, *21*, 693–714. [CrossRef]
67. Visser, F.S. Service design: Tuning the industrial design profession. In Proceedings of the International Association of Societies of Design Research: Consilience and Innovation in Design, Tokyo, Japan, 26–30 August 2013; pp. 1–10.
68. Vladimirova, D. Made to serve. How manufacturers can compete through servitization and product-service systems. *Prod. Plan. Control* **2015**, *26*, 839–840. [CrossRef]
69. Mcaloone, T.C. Boundary conditions for a new type of design task: Product/service-systems. In *The Future of Design Methodology*; Birkhofer, H., Ed.; Springer: London, UK, 2011; p. 315. ISBN 978-0-85729-614-6.
70. Chan, E. New Educational Service Products: Tertiary EC/EB Education—The Asia-Pacific Region. Ph.D. Thesis, Deakin University, Melbourne, Australia, 2003.
71. Van Ostaeyen, J. *Analysis of the Business Potential of Product-Service Systems for Investment Goods*; KULeuven: Leuven, Belgium, 2014; ISBN 9789460188053.
72. Barquet, A.P.B. Creation of Product-Service Systems (PSS) Proposals in the Fuzzy Front-End. Ph.D. Thesis, Universidade de São Paulo, São Carlos, Brazil, 2015.
73. Tukker, A.; Tischner, U. *New Business for Old Europe: Product-Service Development, Competitiveness and Sustainability*; Greenleaf Publishing: Sheffield, UK, 2006; ISBN 9781874719922.
74. Van Erp, J. Designing the total experience—A model for the changing role of the designer. In Proceedings of the The 4th World Conference on Design Research (IASDR), Delft, The Netherlands, 31 October–4 November 2011; p. 9.
75. Cooper, T.; Evans, S. *Products to Services*; The Centre for Sustainable Consumption, Sheffield Hallam University: Sheffield, UK, 2000; pp. 1–61.
76. Visnjic, I.; Turunen, T.; Neely, A. *When Innovation Follows Promise—Why Service Innovation Is Different, and Why That Matters*; University of Cambridge: Cambridge, UK, 2014.
77. Mont, O. *Product-Service Systems: Panacea or Myth?* Lund University: Lund, Sweden, 2004.
78. Haase, R.P.; Pigosso, D.C.A.; McAloone, T.C. Product/Service-System Origins and Trajectories: A Systematic Literature Review of PSS Definitions and their Characteristics. *Procedia CIRP* **2017**, *64*, 157–162. [CrossRef]
79. Stacey, P.K.; Tether, B.S. Designing emotion-centred Product Service Systems: The case of a cancer care facility. *Des. Stud.* **2015**, *40*, 85–118. [CrossRef]
80. Gemser, G.; Kuijken, B.; Wijnberg, N.M.; Van Erp, J. The experience of product service systems. In Proceedings of the Out of Control: The 8th International Conference on Design and Emotion, London, UK, 11–14 September 2012; pp. 11–14.
81. Tan, A.; McAloone, T.; Matzen, D. Service-oriented strategies for manufacturing firms. In *Introduction to Product/Service-System Design*; Springer: London, UK, 2009; pp. 197–218, ISBN 9781848829084.
82. Smith, L.; Maull, R.; Ng, I. Servitization and operations management: A service-dominant logic approach. *Int. J. Oper. Prod. Manag.* **2012**, *34*, 242–269. [CrossRef]
83. Ceschin, F. *The Introduction and Scaling-up of Sustainable Product-Service Systems: Handbook*; Politecnico di Milano: Milan, Italy, 2012.

84. Shostack, G.L. Breaking free from product marketing. *J. Mark.* **1977**, *41*, 73–80. [CrossRef]
85. Goedkoop, M.J.; van Halen, C.J.G.; Te Riele, H.R.M.; Rommens, P.J.M. *Product Service systems, Ecological and Economic Basics*; Dutch Ministries of Environment and Economic Affairs: The Hague, The Netherlands, 1999; pp. 1–132.
86. Edvardsson, B.; Gustafsson, A.; Roos, I. Service portraits in service research: A critical review. *Int. J. Serv. Ind. Manag.* **2005**, *16*, 107–121. [CrossRef]
87. Gokula Vijaykumar, A.V.; Hussain, R.; Roy, R.; Tiwari, A.; Evans, S. A framework for designing product-service systems. In Proceedings of the International Conference on Engineering Design, Lyngby, Copenhagen, Denmark, 15–19 August 2011; pp. 67–76.
88. Maussang, N.; Brissaud, D.; Zwolinski, P. Common representation of products and services: A necessity for engineering designers to develop product-service systems. In *The Future of Product Development*; Springer: Berlin/Heidelberg, Germany, 2007; pp. 463–471.
89. McAloone, T.C.; Andreasen, M.M. Design For Utility, Sustainability And Societal Virtues: Developing Product Service Systems. In Proceedings of the International Design Conference, DESIGN 2004, Dubrovnik, Croatia, 18–21 May 2004; pp. 1545–1552.
90. Mont, O. Clarifying the concept of product—service system. *J. Clean. Prod.* **2002**, *10*, 237–245. [CrossRef]
91. Raijmakers, B.; Thompson, M.; van de Garde-Perik, E. *New Goals for Design, New Roles for Designers?* Cumulus: Helsinki, Finland, 2012; pp. 1–11.
92. Rexfelt, O.; Hiort Af Ornäs, V. Consumer acceptance of product-service systems: Designing for relative advantages and uncertainty reductions. *J. Manuf. Technol. Manag.* **2009**, *20*, 674–699. [CrossRef]
93. Sadek, T.; Köster, M. Analyzing the practical usability of the heterogeneous modeling approach for conceptual product-service system development. In *Functional Thinking for Value Creation*; Hesselbach, J., Herrmann, C., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp. 135–140, ISBN 978-3-642-19688-1.
94. Tan, A.R.; McAloone, T.C.; Myrup Andreasen, M. What happens to integrated product development models with product/service-system approaches? In Proceedings of the IPD 2006: The 6th Workshop on Integrated Product Development, Magdeburg, Germany, 18–20 September 2006.
95. Wild, P.J. *Review of Service Design Methods*; University of Cambridge: Cambridge, UK, 2009; pp. 1–23.
96. Brezet, J.C.; Bijma, A.S.; Ehrenfeld, J.; Silvester, S. *The Design of Eco-Efficient Services*; Delft University of Technology: Delft, The Netherlands, 2001.
97. Creswell, J.W. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*; Sage Publications: Thousand Oaks, CA, USA, 2014; ISBN 9781452274614.
98. Cresswell, W.J. Summary for Policymakers. In *Intergovernmental Panel on Climate Change(ed) Climate Change 2013—The Physical Science Basis*; Cambridge University Press: Cambridge, MA, USA, 2009; pp. 1–30.
99. Nohl, A.M. Narrative interview and documentary method. In *Qualitative Analysis and Documentary Method in International Educational Research*; Bohnsack, R., Pfaff, N., Weller, W., Eds.; Barbara Budrich Publishers: Farmington Hills, MI, USA, 2010; pp. 195–217, ISBN 9783866492363.
100. Coopey, J.; Keegan, O.; Emler, N. Managers' Innovations and the Structuration of Organizations. *J. Manag. Stud.* **1998**, *35*, 263–284. [CrossRef]
101. Silverman, D. *Interpreting Qualitative Data: Methods for Analyzing Talk*; Text and Interaction: London, UK, 2006; ISBN 0-7619-6864-4.
102. Lindahl, M.; Sakao, T.; Sundin, E.; Shimomura, Y. Product/Service Systems Experiences–an International Survey of Swedish, Japanese, Italian and German Manufacturing Companies. In Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference, Cranfield, UK, 1–2 April 2009; pp. 74–81. [CrossRef]
103. Stickdorn, M.; Schneider, J. *This Is Service Design Thinking*; BIS Publishers, B.V.: Amsterdam, The Netherlands, 2011; ISBN 9789063692797.
104. Stickdorn, M.; Lawrence, A.; Hormess, M.; Schneider, J. *This Is Service Design Doing*; O'Reilly Media, Inc.: Newton, MA, USA, 2018; ISBN 9781491927182.
105. Segelström, F. Visualisations in Service Design. Ph.D. Thesis, Linköpings Universitet, Linköping, Sweden, 2010.
106. Spring, M.; Araujo, L. Service, services and products: Rethinking operations strategy. *Int. J. Oper. Prod. Manag.* **2009**, *29*, 444–467. [CrossRef]
107. Verganti, R. Design, meanings, and radical innovation: A metamodel and a research agenda. *J. Prod. Innov. Manag.* **2008**, *25*, 436–456. [CrossRef]
108. Verganti, R. *Design-Driven Innovation: Changing the Rules of Competition by Radicaly Innovating What Things Mean*; Harvard Business Press: Boston, MA, USA, 2009; ISBN 9781422124826.
109. Valencia, A.; Mugge, R.; Schoormans, J.P.L.; Schifferstein, H.N.J. The design of smart product-service systems (PSSs): An exploration of design characteristics. *Int. J. Des.* **2015**, *9*, 13–28. [CrossRef]
110. Maier, R. *Knowledge Management Systems*; Springer: Berlin/Heidelberg, Germany, 2007; Volume 24, ISBN 978-3-540-71407-1.
111. Normann, R.; Ramírez, R. From value chain to value constellation: Designing interactive strategy. *Harv. Bus. Rev.* **1993**, *71*, 65–77. [CrossRef]
112. Cantamessa, M. "Design . . . but of what"? In *The Future of Design Methodology*; Birkhofer, H., Ed.; Springer: London, UK, 2011; p. 315, ISBN 9780857296146.
113. Johne, A.; Storey, C. New service development: A review of the literature and annotated bibliography. *Eur. J. Mark. Manag.* **1998**, *32*, 184–251. [CrossRef]

114. Evans, S.; Cooper, T. Products to Services. Available online: http://www.score-network.org/files//810_8.pdf (accessed on 12 April 2021).
115. Tukker, A. Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet. *Bus. Strateg. Environ.* **2004**, *13*, 246–260. [CrossRef]
116. Vandermerwe, S.; Rada, J. Servitization of Business: Adding Value by Adding Services. *Eur. Manag. J.* **1988**, *6*, 314–324. [CrossRef]
117. Müller, P.; Kebir, N.; Stark, R.; Blessing, L. PSS layer method—Application to microenergy systems. In *Introduction to Product/Service-System Design*; Springer: London, UK, 2009; pp. 3–30, ISBN 9781848829084.
118. Kindström, D.; Kowalkowski, C. Development of industrial service offerings: A process framework. *J. Serv. Manag.* **2009**, *20*, 156–172. [CrossRef]
119. Isaksson, O.; Larsson, T.C.; Johansson, P. Towards a Framework for developing {Product/Service} Systems. In *Functional Thinking for Value Creation*; Hesselbach, J., Herrmann, C., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp. 44–49.
120. Simon, H.A. *The Sciences of the Artificial*; The MIT Press: Cambridge, MA, USA, 2019.
121. Johne, A. Insurance product development: Managing the changes. *Int. J. Bank Mark.* **1993**, *11*, 5–14. [CrossRef]
122. Edvardsson, B.; Olsson, J. Key Concepts for New Service Development. *Serv. Ind. J.* **1996**, *16*, 140–164. [CrossRef]
123. Lievens, A. Project team communication in financial service innovation. *J. Manag. Stud.* **2000**, *37*, 733–766. [CrossRef]
124. Menor, L.J.; Tatikonda, M.V.; Sampson, S.E. New service development: Areas for exploitation and exploration. *J. Oper. Manag.* **2002**, *20*, 135–157. [CrossRef]
125. Eekels, J. The Engineer as Designer and as a Morally Responsible Individual. *J. Eng. Des.* **1994**, *5*, 7–23. [CrossRef]
126. Ruvald, R.; Bertoni, A.; Askling, C.J. A role for physical prototyping in product-service system design: Case study in construction equipment. *Procedia CIRP* **2019**, *83*, 358–362. [CrossRef]
127. Paslauski, C.A.; Ayala, N.F.; Tortorella, G.L.; Frank, A.G. The Last Border for Servitization. *Procedia CIRP* **2016**, *47*, 394–399. [CrossRef]
128. Young, L. *From Products to Services: Insights and Experience from Companies Which Have Embraced the Service Economy*; Wiley: West Sussex, UK, 2008; ISBN 987-0-470-02668-7.