Linköping Studies in Science and Technology
Thesis No. 1757

What's in it for the Provider?

**A Lifecycle-Focused Approach towards Designing for Value
in Product-Service Systems**

Johannes Matschewsky

Environmental Technology and Management
Department of Management and Engineering
Linköping University, SE-581 81 Linköping, Sweden
www.liu.se

© Johannes Matschewsky, 2016

What's in it for the Provider? A Lifecycle-Focused Approach towards Designing for Value in Product-Service Systems

Linköping Studies in Science and Technology

Thesis No. 1757

ISBN: 978-91-7685-696-3

ISSN: 0280-7971

Printed by LiU-Tryck, Linköping 2016

Cover design and photography by author. All illustrations have been created using Inkscape, www.inkscape.org. Dymaxion Map Wireframe used with permission. The Fuller Projection Map design is a trademark of the Buckminster Fuller Institute. ©1938, 1967 & 1992. All rights reserved, www.bfi.org.

Distributed by:

Linköping University

Department of Management and Engineering

SE-581 81 Linköping, Sweden

If we do more with less,
our response will be adequate to take care of everybody.

R. Buckminster Fuller, 1895-1983

Abstract

As the value for customers of Product-Service Systems is increasingly understood, this thesis examines the question: *What's in it for the Provider?* Combining products and services into Product-Service Systems (PSS), which are often owned and even operated by the company offering them, is seen as an important element of conducting more sustainable business. The prospective environmental benefits of PSS lie mainly in the improved resource- and operational efficiency. This is achieved by way of a critical shift in incentive structure: If an industrial company assumes responsibility for an offering throughout the lifecycle, the terms on which that company operates in general are changed notably in comparison to traditional product sales. Instead of benefiting from a short lifetime through additional sales opportunities or making profit through the sale of spare parts, in highly integrated PSS, each parts exchange, each technicians' visit and each day the lifetime of the offering is reduced directly affects the bottom line of the provider. Due to that, solely as a result of economic rationality, a provider of these offerings has an incentive to design in such a way that the life of this offering is prolonged, need for spare parts is reduced, service activities are facilitated and simplified, and that the conditions are in place to allow for a second or third life of the offering through remanufacturing. Regardless of this compelling logic, industrial companies at times fail to establish the preconditions to capturing these benefits as they continue to rely on product and sales-centric design processes even though they provide PSS.

This thesis examines this unexploited opportunity from two vantage points. On the one hand, methods conceived in academia to support industry in implementing and executing joint, lifecycle-focused design of products and services, and the use of these methods in practice, are examined. Here, the focus firstly lies on understanding how PSS are designed today, and secondly, on what should change about PSS design methods to improve their implementability and usability in industrial practice, so that they can fulfill their supposed role as facilitators of efficient PSS design and operation. On the other hand, the possible benefits of providing specifically designed and lifecycle-focused PSS as an industrial company are in focus. To this end, the value attained by providers throughout the use phase of PSS is investigated, to then identify possible approaches towards enhancing this value. Eventually, both focus-areas are joined in an effort to examine the interaction between method-supported, lifecycle-oriented PSS design and the value attained by providers of such offerings.

As a result of the research, a lacking adaptation of design processes to PSS is identified in the case companies. Further, shortcomings of PSS design methods conceived in academia, e.g. excessive complexity, lacking clarity and rigidity, are found in both literature as well as in a study with an industrial company. To take a first step towards rectifying this issue, six characteristics intended to enhance implementability and usability of PSS design methods, are presented. The value attained by PSS providers has been found to be a complex but important

subject. In a case study, value determinants of high relevance to the use phase of the lifecycle have been identified and assessed for their utility as indicators in the evaluation and enhancement of PSS offerings in the design phase. The practitioners involved were supportive of the applicability of the systematic approach presented to capture more value through offering PSS.

In joining both the value- and method-oriented approach, the mutual dependency of both aspects is discussed. In order to provide PSS in an economically and environmentally efficient fashion, adapting the existing design processes is imperative. The value attained by the provider, complementary to existing customer-centric approaches, can serve as an important goal for the adaptation of design processes. Through understanding the change in incentive structure at the core of PSS, and through implementing a value-driven design process supported by efficient and effective methods aimed at providing both customer value and capturing provider benefits throughout the lifecycle, there is an actual potential of conducting more sustainable business.

Acknowledgements

It has now been two and a half years on the roller coaster ride called research – just about the right time to take a breath, look back at what has been done, to then re-focus and set sights on what is to come.

As I have learned in recent years, research is not an endeavor one should embark on alone. There are many people who have, in one way or another, accompanied and supported me to this point, and hopefully, will be just as steadfast by my side as I continue.

First of all, I have to thank my supervisors Mattias Lindahl and Tomohiko Sakao. Mattias, had you not answered my random email some five years ago, all of the pages of this book would have remained blank. I am grateful for your guidance and support, and for your positive and uplifting spirit that can turn any challenge into an opportunity. Tom, I am thankful for the energy and dedication that you continuously and unselfishly invest in supporting me on this path, and hopefully for some shipments of 柿の種 the next time you return from a visit to Japan. A big thank to everyone in the division, to all the senior colleagues for sharing your knowledge, providing feedback and support, with special thanks to Olof Hjelm and Stefan Anderberg, who commented in detail on an earlier draft of this thesis. Big thanks to the PhD Group for being there to discuss and to laugh, and to Maria for having an answer for every possible question. I want to thank my friends Wisdom and Santiago for welcoming me into the PhD student-side of this division back in 2012, and re-welcoming me in 2014, providing much-needed support in the first months and always being there to have a chat about life and the vastness of the universe. You have a huge part in why I absolutely wanted to return to EnvTech. Roozbeh and Paul, thanks a lot for many great and deep conversations. Sergio, thanks for many awesome cappuching-sessions and talks, and thanks Marianna, for making our office a place of fun and focused research alike.

Of course, I want to thank Vinnova, Levor and Navitas for financing this research, and the many respondents for their time, input and support.

A big *Danke für alles!* goes out to my dear family about 850km from here. Sometimes, the distance can feel much greater than the numbers suggest, but then, in years like this, it feels like you are all almost next door.

Lastly, Brini, *mein Herzi*, throughout all of our years, I have felt your unwavering support in every minute. You, without even further considering, have joined me on this journey that has led us way farther from home than we expected to be. With your incredible energy and determination, you have taken this new life that only one year ago, was just mine, and you have made it ours. I am incredibly proud of you, what you have accomplished dwarfs all the words I could ever put onto paper. I look forward to sharing a million laughs with you.

List of appended papers

Paper 1: Matschewsky, J., In Press. PSS without PSS Design - Possible Causes, Effects and Solutions, in: Matsumoto, M., Masui, K., Fukushige, S., Kondoh, S. (Eds.), Sustainability through Innovation in Product Life Cycle Design. Springer Singapore.

Paper 2: Matschewsky, J., Lindahl, M., Sakao, T., 2015. Facilitating Industrial Adoption of Design Methods for Product-Service Systems, in: ICED15: 20th International Conference on Engineering Design. Milan, pp. 301–310.

Paper 3: Matschewsky, J., Sakao, T., Lindahl, M., 2015. ProVa – Provider Value Evaluation for Integrated Product Service Offerings. Procedia CIRP 30, 305–310.
doi:10.1016/j.procir.2015.02.096

Paper 4: Matschewsky, J. Capturing and Enhancing Provider Benefits in Product-Service Systems – A Systematic, Design-Centered Approach. Draft.

Contents

1. Introduction..... 1

1.1 Big Challenges and Small Approaches 1

1.2 Product-Service Systems and the Potential of Changing Incentives..... 2

1.3 The Value of Offering Highly Integrated Product-Service Systems
and Methods Supporting their Design..... 4

1.4 Aim and Research Questions..... 5

1.5 Scope and Limitations of the Research 7

1.5.1 Two Companies in Focus..... 7

1.5.2 Providers of Product-Service Systems 7

1.5.3 The Entire Lifecycle – with a Focus on Design 7

1.6 Thesis Outline 8

2. Frame of Reference 9

2.1 Product-Service Systems 9

2.1.1 Definition and Terminology..... 9

2.1.2 Highly Integrated Product-Service Systems..... 9

2.1.3 Environmental Benefits of Highly Integrated PSS..... 10

2.2 Product-Service Systems Design..... 12

2.2.1 The Need for a Distinct Approach..... 12

2.2.2 Lifecycle Focused Design for Highly Integrated PSS..... 13

2.3 Value as a Concept for PSS Design 14

2.3.1 Value in Marketing and Relationship Management Literature
in Context to PSS Design..... 14

2.3.2 Value in Sustainability-Oriented PSS Design Research..... 15

2.3.3 A Provider-Focused Understanding of Value in PSS..... 16

2.4 Organizational Challenges and Internal Company Relationships..... 16

2.5 Building the Frame – The Interrelations between Different Elements..... 18

3. Methodology 19

3.1 Research Approach 19

3.2 Research Methods 22

3.2.1 Literature Reviews 23

3.2.2 Questionnaires 24

3.2.3	Participant Observation.....	25
3.2.4	Actor and System Mapping Workshops	25
3.2.5	Provider Value Analysis (PVA) in an Expert Interview.....	26
3.2.6	Provider Value Evaluation (ProVa)	28
3.3	Reflecting upon Research Journey and Methods.....	29
4.	Contributions and Summaries of the Appended Papers.....	31
4.1	Connection between Papers and Research Questions	31
4.2	Paper 1 – PSS without PSS Design – Possible Causes, Effects and Solutions	31
4.3	Paper 2 – Facilitating Industrial Adoption of Design Methods for Product-Service Systems	32
4.4	Paper 3 – ProVa – Provider Value Evaluation for Integrated Product Service Offerings	33
4.5	Paper 4 – Capturing and Enhancing Provider Benefits in Product- Service Systems – A Systematic, Design-Centered Approach.....	34
5.	Exploring the Status Quo – PSS Design Processes and Methods	37
5.1	Inherent Challenges of PSS Design Methods	37
5.1.1	Learning from Others: Engineering Design and Ecodesign	37
5.1.2	The Value of Methods.....	37
5.1.3	Challenges for Method Adoption across Engineering Design, Ecodesign and PSS Design	38
5.2	Offering PSS vs. Designing PSS: Crucial Differences.....	39
5.2.1	Customer Pressure and Understanding Changed Incentives	39
5.2.2	The Unheard Voice of Internal Stakeholders that are Key to PSS Design	41
5.2.3	Managerial Focus and a Dominating Product-View	41
6.	Shaping an Understanding for the Provider’s Value in Offering PSS	43
6.1	Introduction	43
6.2	Initial Hypothesis for Provider’s Value.....	43
6.3	An Industry-Supported Understanding of Value for PSS Providers.....	44
6.3.1	Exploring Multidimensionality in Value for Providers	44
6.4	Exploring the Relevance of Provider-Centered Value on PSS Design	45

6.4.1	Applicability of Use Phase-Oriented Value Conception in PSS Design Process.....	45
6.4.2	Impact of Value Evaluation on Design Process Adaptation.....	46
7.	Discussion	49
7.1	Companies and Methods – Two Sides of the same Design Adaptation-Coin	49
7.1.1	The Company View – Challenges in Design Method Adaptation	49
7.1.2	A Focus on Methods – Better Design for Improved Implementability and Usability.....	50
7.2	Understanding the Value in Offering Highly Integrated PSS.....	52
7.2.1	General Conceptualization of Provider’s Value.....	52
7.2.2	Towards Common Value Dimensions for Highly Integrated PSS	54
7.2.3	Provider-Centered Value for PSS Design	56
7.3	Analyzing the Interdependency between Process Adaptation, Value and Methods	57
7.4	Managerial and Environmental Implications.....	61
7.4.1	Environmental Implications.....	61
7.4.2	Managerial Implications	62
8.	Conclusions and Outlook.....	63
8.1	How Companies have adapted their Design Processes to PSS.....	63
8.2	Potential Means of Facilitating Improved PSS Design	63
8.3	How the Value Attained by Providers throughout the PSS Lifecycle is characterized	64
8.4	How the Understanding of the Providers’ Value in Offering PSS can be operationalized	64
8.5	Concluding Remarks.....	64
8.5.1	Method Value Synergies: The Takeaway	64
8.5.2	Generalizability	65
8.5.3	Outlook and Future Research	65
	References.....	67

List of Figures and Tables

Figure 1 – PSS Business Models..... 9

Figure 2 – Relation between freedom of action, modification cost..... 13

Figure 3 – Approach to product and service design..... 17

Figure 4 – Illustration of research approach and logic between research foci. 20

Figure 5 – Mockup of data gathering document for Provider Value Analysis 26

Figure 6 – Process of Provider Value Evaluation method 28

Figure 7 – Changes in incentives comparing product sales to PSS..... 40

Figure 8 – Value in product sales vs. value in highly integrated PSS 53

Figure 9 – Relationship between design methods, design process and value..... 57

Figure 10 – Freedom of action in design vs. actual value creation and capture..... 58

Figure 11 – Interaction between design and use phase to increase value 60

Table 1 – Overview of the relation between individual papers and methods used..... 22

Table 2 – Contribution of the papers to the respective research questions..... 31

Table 3 – Challenges for method adoption as identified in the literature 38

Table 4 – Results of evaluation of influential method properties 39

Table 5 – Identified value dimensions with the importance for the providers 44

Table 6 – Ranking of clustered value dimensions for relevance in design process 46

Table 7 - Characteristics intended to enhance the implementability and usability 51

Table 8 – Clustered value dimensions, descriptions and relevant references 55

1. Introduction

Beginning on a global scale and quickly narrowing to the scope of the research, this section introduces both the incentive for the research and its operationalization in the form of research questions as well as its relevance for both academia and practice.

1.1 Big Challenges and Small Approaches

There is an inherent conflict of interest between the two main challenges humanity is currently facing. On the one hand, there are extreme poverty and harsh living conditions for a substantial portion of the world's population¹. On the other hand, environmental degradation, resource depletion and climate change pose a substantial threat to the welfare of future generations (Stern, 2007). Improving these conditions, particularly with a focus on the developing countries, appears to be dependent upon economic growth (Basu, 2013; Bhagwati et al., 2013). In the past decades, a growth focus proved to be successful², as e.g. the share of people living in extreme poverty has been reduced from 37.1% to 9.6% between 1990 and 2015, which amounts to a reduction of two thirds in absolute numbers (from 1,959 million to 702 million people) due to the exponential growth in human inhabitants, which particularly impacts the poorer countries of the world (World Bank Group, 2016). However, although the recent past may look promising, the future is bleak: As a result of environmental degradation, resource depletion and climate change, the danger of the advances made with respect to fighting poverty being lost or even reversed is substantial (Edenhofer et al., 2014; Stern, 2007). Bringing growth and resource use into balance is an issue that calls for far-reaching measures on all levels of society, and in all societies. Concepts such as “de-growth” (Schneider et al., 2010), in their adherence to the concept of growth as a measure for welfare and prosperity, appear not to be a viable alternative at this time at great scale (van den Bergh, 2011). Therefore, where grand solutions cannot be reached, time calls for pragmatic approaches, unravelling one problem at a time with the aim of supporting all stakeholders involved³. The key stakeholders addressed here are industrial companies, as these contribute

¹ There is an obvious challenge in measuring these aspects, as they rely on the interpretation of existing data and on boundary setting, which can at times be arbitrary and fueled by political agenda. According to the World Bank's current statistics, the boundary for extreme poverty is set at USD 1.90 per person/day (World Bank Group, 2016). Although the current measure is a substantial increase from the earlier USD 1.25, the criticism brought forward by scholars such as Angus Deaton with respect to the arbitrary nature of this generalist measurement still applies (Deaton, 2010).

² It must be mentioned, that a growth focus under the premise of economic liberalization, as e.g. driven by the International Monetary Fund in recent decades, is suspected to have had notable adverse effects, such as civil unrest (Hartzell et al., 2010) and higher income disparity (Ostry and Berg, 2011).

³ This points to the question of radicalism vs. incrementalism, particularly with respect to a policy level (see e.g. Rosenbaum, 2013, 43 ff.).

more than 20% to Sweden's GDP (OECD, 2016). In this thesis, particular approaches to conducting more sustainable⁴ business are discussed, and therein particularly the design of industrial offerings as well as the value they can actually generate.

For some decades, research has been conducted on the topic of reducing the environmental impact of industrial activities. Substantial advancements have been made in the area of the design and construction of physical artifacts: The field of Ecodesign (Brezet et al., 1997) has contributed a large amount of knowledge on improved design procedures, materials and artifact use (see e.g. Pigosso et al., 2013). However, since the advantages of implementing Ecodesign often benefit the consumer, and not the producer of the artifacts, the incentive for producers to implement these measures within their organizations is low⁵. The main benefits identified by Plouffe et al. (2011) result from higher customer interest due to cost reductions in the design of the products. In order to enhance producers' motivation to implement Ecodesign, an extended responsibility for their offerings is seen as a possible measure (Gottberg et al., 2006), although even this aspect relies on the necessary political framework being implemented in order to attain a level playing ground among competitors. Thus, a main challenge must be to achieve a situation where the economic incentive of increasing profits coincides with environmental benefits. A solution to this can neither be universally applicable nor transferable to all situations and countries, but, should it function in certain sectors and regions, the lessons learned may be transferable on a more general and abstract level.

1.2 Product-Service Systems and the Potential of Changing Incentives

Integrating products and services into "a marketable set of products and services capable of jointly fulfilling a users' need" (Goedkoop et al., 1999) is not an entirely new concept: Mont (2002) mentions the example of the Kodak Single Use Camera, which were taken back by Kodak, who then provided developed negatives to the customers, while re-equipping the cameras with film and returning them to stores to be sold once again (Goldstein, 1994). This service was available as early as the 1980s (Goldstein, 1994). Although essentially not novel, the concept of Product-Service Systems (PSS) has received increased attention in both research and practice since the early 2000s (Tukker, 2015). PSS entail the possibility of creating added value, and thus growth, while disconnecting this growth from increased material consumption and resource depletion (see e.g. Manzini et al., 2001).

PSS go far beyond a mere integration of products and services into a bundled offering. A lifecycle perspective is added and concentrated on providing functions, service and performance (Lindahl et al., 2006). The integration of products and services in PSS manifests itself

⁴ Both in the sense of economic and environmental sustainability.

⁵ It appears to require political action and legislative pressure to enforce new design standards, as done e.g. on the matter of vacuum cleaners on the level of EU legislation (European Commission, 2013).

on different levels, reaching from function-oriented, through availability/use-oriented all the way to result-oriented business models for PSS (Meier et al., 2010; Tukker, 2004)⁶. Inherent to this transition is also the increasing responsibility shift from the customer to the provider throughout all of the lifecycle phases, leading to the provider of PSS lastly retaining the ownership and control of the offering. PSS with such a high level of integration⁷ can be referred to as *highly integrated* PSS (Miller and Mattes, 2014). A provider is here understood as an industrial company that designs, markets and at times even remanufactures these offerings (see Martinez et al., 2010; Sakao and Lindahl, 2015). It is highly integrated PSS that are of greatest interest here, as particularly with them constellations may be found that benefit both the PSS provider and customer, as well as external stakeholders such as society and the environment (Tukker, 2015). The case companies in focus in this research are identified to be providers of highly integrated PSS. Further, the term Integrated Product Service Offering (IPSO) is prevalent in academia, also with a focus on the integrational aspect.

In contrast to the aforementioned Ecodesign, highly integrated PSS contain inherent incentives that motivate providers to actually change their business model, ideally achieving reduced environmental impact, e.g. through reduced resource use and increased operational efficiency (Vezzoli et al., 2015). Due to the responsibility of the provider of highly integrated PSS for the use and end-of-first-life phases of the offering, benefits throughout the lifecycle that were previously beneficial to the customer now become an advantage that the provider can attain. Through this, economic incentives for the customer and provider as well as benefits for external stakeholders are ideally aligned into a win-win-win scenario between the customer, provider and surrounding society. Although the knowledge basis is at this point still narrow, highly integrated PSS have been shown to be superior to product sales with respect to environmental as well as economic performance. Lelah et al. (2011) have shown reductions in global warming and energy depletion indicators over the lifecycle of a PSS, and Lindahl et al. (2014) have found environmental as well as economic benefits when comparing PSS and product sales offerings. Nonetheless, there is no automatism between offering PSS and improved environmental performance: A number of preconditions must be fulfilled to have the prospect of offering sustainable PSS, including design, production, distribution and end-of-life (Manzini and Vezzoli, 2003; Tukker, 2015; Vezzoli et al., 2014). Rebound effects as a result of the effectiveness improvements associated with PSS are a topic frequently discussed in the literature (Hertwich, 2008), which pose a challenge for companies and policy-makers alike.

⁶ Further aspects of the various levels of differentiation among PSS business models are elaborated upon in Section 2.1.2.

⁷ This includes some availability/use-oriented as well as all result-oriented PSS.

1.3 The Value of Offering Highly Integrated Product-Service Systems and Methods Supporting their Design

Only bringing to market highly integrated PSS is not enough to ensure improved performance of any kind. Research has shown that PSS require design approaches, methods and tools that diverge substantially from those conceived with traditional product sales in mind, and thus necessitate far-reaching changes to existing processes (Diehl and Christiaans, 2015; Wolfenstetter et al., 2015). A substantial number of methods and tools aimed at facilitating the development of PSS has been presented in the past roughly one-and-a-half decades (Vasantha et al., 2012), although scholars generally concur that the levels of adoption of these methods is surprisingly low. Rather, companies leave their pre-existing design processes untouched and merely add services as an afterthought (Wolfenstetter et al., 2015). Therefore, although a business model transition⁸ is carried out, design processes often do not follow suit. It is imperative for the academic community and, in turn, its industrial partners, to investigate the question of why academically developed methods for PSS design are hardly utilized by companies, with the result of economic and environmental improvement possibilities remaining untapped. Deriving a deeper understanding for this issue from an academic as well as a practitioner perspective is therefore a central goal of the research presented here (Geis et al., 2008).

The availability and implementability of adequate methods for the design of PSS alone is insufficient to assume a notable change in the business models adopted by companies. In order for companies and their managers to be encouraged to move towards becoming a PSS provider, they must be able to answer, whether consciously or not, a central question: What is the value in offering PSS?⁹ It is the underlying presumption of this research that this question leads towards two main trajectories, with some overlap, but which also differ substantially in other ways: The value to the customer and the value to the provider. With traditional product sales, although not entirely without complexity, the answer to this is quite straightforward: The customer gains value-in-use throughout the use phase of a product, and the provider gains value-in-exchange at the time of the sale (Grönroos and Voima, 2013) in the form of monetary value. Through the close and long-term relationship between customer and provider throughout the PSS lifetime (Meier et al., 2010), value creation is a more complex process in the case of PSS. The value creation for PSS customers has been examined in-depth in the immediate research field (Arai and Shimomura, 2004; Kimita et al., 2009a; Shimomura

⁸ As discussed in Section 2.4, a full transition is often not completed. Rather, both product sales as well as PSS offerings are offered in parallel, further adding complexity to already challenging circumstances.

⁹ In other words: What is to be gained by offering PSS? And where is the difference to selling products? The transition will only be carried through if the anticipated benefit is high enough to justify the cost of said transition.

et al., 2009), and methods have been developed for assessing customer value during the design of PSS (Sakao and Lindahl, 2012). However, the value that is attained by offering PSS for providers has not been examined in-depth. Where the benefits for PSS customers in an increasing focus on core business (Ceci and Prencipe, 2008) are well-understood, an in-depth and multidimensional approach to what is gained by PSS providers throughout the lifecycle has not yet been taken.

At first, the connection between PSS design methods and the value generated for the provider by these offerings throughout their lives may appear elusive. However, even though PSS design and the actual generation of value are found in different phases of the lifecycle, they are mutually dependent. Without a dedicated and well-adapted PSS design process, there will be lost value creation opportunities throughout the life of the offering – and without making use of the lessons learned about the actual value creation in the use phase and beyond, even the best and most focused design procedure is rendered to the level of vague guessing. This is particularly true when a company is still in the early phases of implementing a PSS business model and struck by many of the associated challenges (Windahl, 2007).

As a result, the research presented investigates both PSS design and methods designed to be utilized in its process, as well as the value created through PSS. Ultimately, the connection between these matters is discussed.

1.4 Aim and Research Questions

Based on the above, the aim of this research is *to develop a deeper understanding for PSS design as currently performed in industrial practice, to identify opportunities for facilitating the adoption of PSS design methods, and to examine the value that can be attained throughout the lifecycle by providers offering highly integrated PSS*. The aim presented is essentially twofold, while the convergence of the two streams aims to jointly elevate the lessons learned in both areas.

On the one hand, the aim is to *explore the approaches towards PSS design currently used in companies offering highly integrated PSS, and to derive and synthesize guidelines for the improvement of the implementability and usability of methods conceived to support the adaptation of design processes in industrial practice*. On the other hand, the research aims to *derive a deeper understanding for the value created for the provider throughout the life of these offerings*. In joining both streams, the research efforts shown aim to *operationalize the derived understanding of value for use in the PSS design process, in hopes of lifting the value created with respect to the stakeholders directly or indirectly involved*.

The presented aim is operationalized through the following research questions:

RQ1: How have companies adapted their design processes to offering highly integrated PSS?

An increasing number of companies is bringing offerings to the market that can be described as highly integrated PSS. In order to establish a point of departure to discuss the implementation of PSS design methods further in RQ2 as well as to address understanding and operationalizing potential value for PSS providers in RQs 3 and 4, an understanding for the way PSS are currently designed is needed. In response to this RQ, not only is the current state of the adaptation of design processes of PSS providers discussed, but the possible results of this situation are evaluated and ways forward are outlined.

RQ2: What are the potential means of facilitating improved PSS design through the implementation and use of PSS design methods in industrial practice?

In this research question, two aspects of PSS design method implementation are evaluated: (1) The side of the methods themselves, (2) and the side of the companies implementing and the engineers using them. With regard to PSS design methods, concepts and approaches are sought to improve the usability and implementability of these methods through companies. With respect to the companies, the circumstances under which PSS are designed and methods potentially used are evaluated in order to identify improvement potentials.

RQ3: How can the value attained by providers throughout the PSS lifecycle be characterized?

To be able to meaningfully adapt design processes for highly integrated PSS, the incentives behind taking on this shift should be understood. The current product- and cost-oriented approach is insufficient to truly understand the complexity of the value attained by PSS providers throughout the lifecycle. In answering this question, the aim is gain a deeper understanding of the benefits attained by offering highly integrated PSS.

RQ4: How can the understanding of the providers' value of offering highly integrated PSS be operationalized for applicability in the PSS design process?

In order for the understanding attained to be of higher utility to industrial practice, an operationalization of the value identified in RQ3 for use in the design process of PSS providers is to be achieved. Through this, the goal is to increase the accessibility and clarity of the providers' value in PSS and to improve the chances of this approach impacting the performance of coming offerings in aspects of both environmental and economic relevance.

1.5 Scope and Limitations of the Research

Since this work is the result of roughly two-and-a-half years of research, many interesting aspects could not yet be covered, both with respect to the broadness as well as the depth of the research. In this subsection, the scope and delimitations of this thesis are illustrated.

1.5.1 Two Companies in Focus

In the empirical elements of the research presented, two companies are in focus. For both, anonymized names are used throughout this thesis as well as in the appended articles to ensure the confidentiality of the industrial partners. The first, *Levor*, developed from only being a producer of industrial equipment to also becoming a provider of integrated offerings of products and services to its industrial customers, roughly through the past 20 years. The second is *Navitas*, a supplier of investment machinery, which has recently begun a transition to taking over increasing activities from its customers. Both of these companies represent industrial actors with a design and production-oriented heritage and are, in the form of their parent companies, active on a global scale. As indicated by Tukker (2015) and the references therein, the business and environmental advantages are expected to be substantially more profound in the case of business-to-business relationships. Further, the research presented in the articles referenced by Boehm and Thomas (2013), Reim et al. (2015) and Tukker (2015) relies largely on “industrial companies”, i.e. companies with a product sales and design focus prior to extending their offerings to PSS. For these, both Levor and Navitas are fitting examples, as they are in different stages of developing and bringing their PSS offerings to market, and thus the challenges currently experienced by them may be complementary. However, these companies are of course not representative of small and medium-sized enterprises (SMEs), which may observe other struggles. Nonetheless, with respect to the actors in the field of corporations covered by a substantial portion of the literature in the field (ibid.), the companies participating in the research presented here are assumed to be a relevant addition and a good fit with regard to the extension of prior knowledge.

1.5.2 Providers of Product-Service Systems

Inherent to the logic of mainly focusing on two companies is that in this thesis, through this focus, the concept of a PSS provider is characterized. The PSS provider is the main entity composing and providing the integrated offering of products and services (Aurich et al., 2010; Martinez et al., 2010; Sakao and Lindahl, 2015). Therefore, this view concentrates on the “node” of the PSS offering, which is present throughout the lifecycle.

1.5.3 The Entire Lifecycle – with a Focus on Design

The work presented aims to take into account the entire lifecycle – a key aspect of PSS in both an environmental as well as economic sense (Tukker, 2015) – in order to reflect upon and have impact on the design process of PSS. For that reason, the knowledge gained through empirical work in the use phase of the lifecycle is utilized in order to reflect back upon the

design process and its prescriptive impact. This is done in accordance with the reasoning that the highest degree of freedom is available at the beginning of the design process (Lindh, 2005). In congruency with the views of many fellow researchers (e.g. Diehl and Christiaans, 2015; Qu et al., 2016; Vasantha et al., 2015), and in awareness of its substantial importance, the distinct focus on the design process of PSS was determined.

1.6 Thesis Outline

This thesis is structured as follows: In Section 2, the literature-based background of the main aspects of this research work is elaborated upon. Thereafter, Section 3 introduces the methodological approach and the methods used to answer the research questions. In the subsequent Section 4, all of the appended papers are summarized, with key information being given on each paper's aim, method used and contribution made to this thesis. In the following Sections 5 and 6, the results of the research with respect to the two overall foci discussed in the aim are presented. Thereafter, in Section 7, these results are analyzed and discussed. Lastly, Section 8 concludes the thesis and provides an outlook on future research trajectories and efforts.

2. Frame of Reference

This section presents the theory and concepts, which lie at the basis of the research conducted.

2.1 Product-Service Systems

2.1.1 Definition and Terminology

PSS are offerings consisting of products (tangible goods) and services (intangible goods), which are jointly developed and brought to market with a focus on fulfilling a customer’s needs (Goedkoop et al., 1999). Product-Service Systems (PSS) constitute a possible way to create value while decreasing the environmental impact of the offering PSS (see e.g. Mont, 2002). Deeper insight into the field may be provided by the recent reviews of Tukker (2015), Boehm & Thomas (2013) and Hänsch Beuren et al. (2013).

There are a wealth of other terms utilized for combined offerings of products and services, although often times the focus varies. This means that the focus may lay more on the product or the service aspect, and even on different levels of integration between the two. In *Integrated Product Service Offerings (IPSO)*, particular focus is put on the integrative development of products and services (Lindahl et al., 2006). Vezzoli et al. (2015) draw focus to the environmental aspect by discussing *Sustainable Product-Service Systems (S.PSS)*. Even though the terms available to describe the concept of PSS are numerous, most often, the same meaning is conveyed by them (Sundin et al., 2009).

2.1.2 Highly Integrated Product-Service Systems

As discussed in Section 1.2, PSS can be offered with different levels of integration. Figure 1 shows the different PSS business models, where the value creation is shown as a continuum between product and service.

Figure 1 – PSS Business Models (Meier et al., 2010; Tukker, 2004)

Where function-oriented PSS still leave the majority of the responsibility with the customer, availability/use-oriented PSS see an increasing takeover of the responsibilities for servicing and maintenance through the provider – even changes in ownership structure become apparent. With result-oriented PSS, the ownership and operation of the offering is transferred

to the provider. The term highly integrated PSS (Miller and Mattes, 2014) is used to describe both result-oriented PSS and availability/use-oriented PSS that have a strong provider involvement throughout their entire lifecycle. This may be signified by the ownership structure and end-of-life treatment of the offering through the provider.

Example of Highly Integrated Product-Service Systems

In order to also ensure a common understanding also for a readership not immediately familiar with the concept of highly integrated PSS, the following example should, in very general and simplified terms, describe the nature of this offering:

Assume that, in a product sales scenario, a company previously was the seller of road-cleaning machines, which were sold to municipalities. This company may have gained some revenue by offering services for these machines, but the main source of income would have been the actual sales. Should this company decide to become a provider of highly integrated PSS, the offering would change substantially: Instead of selling machines, the company now provides clean surfaces. It takes care that the machines are in working order at all times and even supplies the operators for the machines. This means that the municipalities get billed based on the area they would like to have cleaned, and on the cleaning intervals. Both sides can profit from this, e.g. in the form of planning security (long-running contracts). For the provider, there is now a major change in incentive structure: Where previously there was money to be earned in replacing parts, e.g. the sweeping brushes of the machines, now these replacements become costs. There is now an incentive to make parts last longer, *if* the lifecycle cost of these parts is then lower. That means, e.g., that changed brush design, which costs 30% more but extends the lifetime by 60%, is economically viable. In addition, as less material is used throughout the lifecycle, environmental benefits are incurred. Further benefits may be improved operational efficiency, since the provider has the best knowledge on how to operate the machine. However, in order to be able to attain these benefits, highly integrated PSS must be designed from the ground up with a lifecycle focus and through integrating products and services.

2.1.3 Environmental Benefits of Highly Integrated PSS

The capabilities of the PSS business model in reducing the environmental impact of industrial activity have been discussed at length in the literature. A trend is notable in published research, from largely theoretical discussions around the time the PSS term was conceived, to an increased focus on quantitative verification of the environmental benefits of PSS in recent years, a chronologic development also notable within this subsection.

In most cases, the benefits are related to improvements in resource efficiency, which can be achieved in different ways. Goedkoop et al. (1999) mention the unlinking potential of PSS, referring to the opportunity to decouple economic growth from “environmental pressure”. Except for this, the authors largely point to traditional and well-known aspects which also apply other efforts with a focus on sustainability, e.g. image improvement, extended provider responsibility, or environmental cost reduction. Mont (2002b) provides a much more comprehensive initial account of how the minimization of environmental impact is a “paramount goal of product-service systems”. Aspects of this mentioned by Mont (2002b) are closed material cycles, reduced consumption through alternative scenarios of product use, increasing overall resource productivity and dematerialization of PSS, as well as efficiency improvements within a system where all parts are utilized to a high extent. The author further mentions that these were of a theoretical nature at the time of publishing, but that some elements can be found in companies, and these are “mainly driven by business and economic considerations”. This points to the capability of PSS to promote business activity where improvements in value generation coincide with improved efficiency, and therefore environmental performance (see also Section 1.2). The issues discussed above have, for the most part, a common denominator: They depend on the implementation of highly integrated PSS. This has been discussed by Tukker (2004): When discussing different types of PSS offerings, he attributes the most extensive and notable environmental benefits that can be expected to “result-oriented services”. With varying levels of explicitness, the same is true for Mont (2002b) and other conceptual and review papers (among others Baines et al., 2007; Manzini et al., 2001; Meier et al., 2010; Tukker and Tischner, 2006; Tukker, 2015).

Particularly up to ca. 2010, many authors noted that the expected environmental benefits of PSS are of largely theoretical nature (see e.g. Mont, 2002b; Tukker, 2004). Subsequently, the first quantitative accounts focused on the environmental benefits of PSS have been published. When evaluating a result-oriented PSS, Lelah et al. (2011) were able to show a substantial reduction in indicators such as energy depletion and global warming throughout the lifecycle of PSS. More recently, Lindahl et al. (2014) reported environmental as well as economic benefits of highly integrated PSS when compared to traditional product sales offerings, particularly when paying close attention to the entire lifecycle with respect to cost and environmental impact (see Sakao and Lindahl, 2015). Very recently, the focus on the implementation of PSS in a sustainability context has increased, putting growing weight on the interconnectedness of environmental benefits of PSS and PSS design (Vezzoli et al., 2015).

2.2 Product-Service Systems Design

2.2.1 The Need for a Distinct Approach

PSS differ in such a profound way from traditional product-type offerings, that they require their own methods and tools (Morelli, 2006; Sakao, 2011). The need for a dedicated PSS design methodology has been discussed by a number of researchers for various reasons, e.g.:

- “...a broader range of knowledge is required to design PSS, since both products and services are included in the design space.” (Akasaka et al., 2012)
- “To design PSS, a new method is required to support those who engineer a PSS effectively and efficiently.” (Sakao, 2011)
- “...a PSS may need to be specifically designed, developed and delivered, if it is to be highly eco-efficient.” (Vezzoli et al., 2015)
- “Developing a PSS incorporates the integration of components from multiple engineering disciplines such as mechanical engineering, software engineering and service engineering. In this regard it does not make sense to separate the development into domain-specific processes.” (Wolfenstetter et al., 2015)

Nonetheless, PSS design has its roots firmly planted in the tradition of product-oriented engineering design. According to Blessing and Chakrabarti (2009), engineering design is “activities that actually generate and develop a product from a need, product idea or technology to the full documentation needed to realize the product and to fulfil the perceived needs of the user and other stakeholders.” In the case of PSS design, the scope is broadened to include the *joint* design of products and services with a focus on the lifecycle of the offering (Mont, 2002b), including the end-of-life, ideally in the form of remanufacturing (Sakao and Mizuyama, 2014).

A substantial number of methodologies (e.g. Sakao et al., 2009; van Halen et al., 2005; Vezzoli et al., 2014), methods and tools (e.g. Bertoni et al., 2013; Müller et al., 2009; Sakao and Lindahl, 2012) have been published in the past decade to support practitioners throughout the PSS design process. Further, a review has been published comparing and discussing eight different PSS design methodologies (Vasanthi et al., 2012). The scope of these publications varies substantially, as some are focused on encompassing the entire design process (van Halen et al., 2005), while others aim to solve very particular tasks during the PSS design and development process (Lim et al., 2012).

It appears, though, that similarly to established engineering design (see e.g. Andreasen (2011) and Jänsch & Birkhofer (2007)) the tools, methods and methodologies developed lack a broad acceptance and use in industry (Vezzoli et al., 2015).

2.2.2 Lifecycle Focused Design for Highly Integrated PSS

When designing and offering PSS, assuming a lifecycle perspective is critical in order to be able to design effectively and efficiently and to deliver and attain high value for customers and providers. Particularly in the case of highly integrated PSS, providers stay in close contact with their offering throughout the lifecycle – if this aspect is not taken into account from the earliest stages of design, inefficiencies and missed value creation opportunities are likely the result.

As with engineering design in general, the decisions made early in the design process significantly influence the outcomes throughout the life of the offering. What is more, the freedom to make changes plunges sharply after the first design decisions have been made (Lindahl, 2005). This is conveyed by the relationship between freedom of action, modification cost and product knowledge shown in Figure 2.

Figure 2 – Relation between freedom of action, modification cost and product knowledge over time (Lindahl, 2005)

In the case of highly integrated PSS, the impact of the relationship between the three indicators shown in Figure 2 is even more profound. Even though an offering may appear highly beneficial when the design process is completed and it is brought to market, it may turn out not to be profitable concerning the whole life of the offering. Highly integrated PSS bring about a substantial change to the incentive structure of an offering: Whereas previously,

providing services and exchanging parts was seen as a source of revenue, in highly integrated PSS, this becomes a cost (Manzini and Vezzoli, 2003; Tukker, 2015; Tukker and Tischner, 2006).

Settanni et al. (2015) have pointed out that in cost calculations for PSS, very often similar approaches as in product sales and the respective services are used. Even more so, identical terminology is often employed, which further hinders a true shift of perspective towards a lifecycle focus. In addition, companies often still set costing targets for out-of-the-gate cost, even though they offer highly integrated PSS and thus remain the owner of the physical parts of the offering. It remains to be explored if this approach leads to a suboptimal lifecycle cost and missed value creation opportunities.

Moving beyond the use phase of highly integrated PSS, such an offering retains substantial value even when the end of its first life has been reached. Planning early for efforts such as remanufacturing may support further value creation – in this case, provider's value in particular. A number of publications have focused on the relationship between PSS and remanufacturing (see e.g. Mont, 2002; Sakao and Mizuyama, 2014; Sundin et al., 2009, 2008).

2.3 Value as a Concept for PSS Design

As remarked by Fernandes (2012), the topic of value is discussed in many different research fields, has undergone substantial changes over time and has been discussed as early as in Aristotelian time (Vargo et al., 2008). Nonetheless, a broad consensus on the understanding of value has not yet been reached (Fernandes, 2012). This subsection aims to elucidate the concept of value in close relation to the topic at hand – PSS design. First, the value concept as discussed by scholars in marketing and relationship management with relevance for PSS design is introduced. Thereafter, previous research focusing on value in literature more or less directly focused on PSS is presented. Lastly, existing publications on the topic of value to providers of PSS are discussed.

2.3.1 Value in Marketing and Relationship Management Literature in Context to PSS Design

The concept of value in an engineering design context has been pioneered by Miles (1971). There, value is proposed to be a relation of function (or performance) over cost. Therefore, more value can be created by either increasing performance while cost remains stable, or decreasing cost for the same performance. In scientific fields adjacent to PSS research, the concept of value plays an important role: Research in marketing and relationship management has long investigated the concept of value with varying focus and different implications.

With regard to the topic of this thesis, research on service-dominant logic (Vargo and Lusch, 2004) bears particular relevance: Where previously value was understood as contained in physical artifacts (goods-dominant), a new logic is proposed, focused on the performance of

services where value is co-created with the customer. Value creation under such a premise has further been broadly researched in the marketing domain (Grönroos, 2008; Grönroos and Ravald, 2011; Payne et al., 2007), with a strong customer focus. More recently, Grönroos and Voima (2013) have discussed the concept of value for both customer and provider: Where previously, value for the provider was generated as value-in-exchange at the point of sale, under a service-dominant logic, value creation encompasses all activities of the customer and provider. Grönroos and Voima (2013) further stress the subjectivity of value and its relation to customer perception. As pointed out by Panarotto (2015), the concept of value has, among some scholars, come to encompass more than cost alone (Grönroos and Voima, 2013; Steiner and Harmon, 2009), e.g. intangible value, which goes beyond monetary aspects by including elements such as knowledge, experience and emotion. Notable research efforts have been put in e.g. examining the nature of the aspect of intellectual capital (knowledge) as one of the major value drivers for companies (Dumay, 2014; Vallejo-Allonso et al., 2010). Naturally, there are substantial challenges in making these various aspects measurable and using them as a basis for managerial and engineering-oriented decision-making, and thus, they require more research (Sullivan and McLean, 2007).

The concept of value is discussed on a broad scale and is the subject of a vast amount of research in the mentioned fields. Researchers in the area of PSS have therefore in recent years aimed to operationalize this knowledge to facilitate its use in the actual design process, which is decisive for the value created throughout the lifecycle of an integrated offering with a sustainability-focus (Bertoni et al., 2013). This aspect is discussed in the following subsection.

2.3.2 Value in Sustainability-Oriented PSS Design Research

PSS research also expresses a strong focus on value creation for the customer (Goedkoop et al., 1999; Mont, 2002b). Value co-creation has strong implications on how both customers and providers of service-based offerings interact and perceive their role (Vargo et al., 2008), and this in turn impacts the design of these offerings, not least of their physical components. Up to now, research in this area has mainly highlighted the aspect of customer value in a PSS offering (Kimita et al., 2009a, 2009b). In their work on service engineering, Sakao and Shimomura (2007) define value as a change of state for the receiver of the service, which is deemed preferable by this entity. This is in line with the research on service-dominant logic introduced above. Efforts have been made to include the value aspect into the PSS design process, e.g. in the form of a customer value evaluation (Sakao and Lindahl, 2012) or as a visualization tool during the CAD-based design process (Bertoni et al., 2013). Further, criteria have been discussed to assess the value of different design alternatives (Bertoni et al., 2011).

The work on value-driven design (Collopy and Hollingsworth, 2012) bears great relevance for PSS design research focused on value, as also mentioned by (Bertoni, 2013; Bertoni et al.,

2013). Value-driven design puts focus on system-level optimization already in the early stages, making it relevant for research on the design of resource-efficient PSS (Isaksson et al., 2015). Panarotto (2015) has further introduced a value-focused method for the conceptual design phase, focusing on models instead of the otherwise widely used mathematical optimization in value-driven design.

In their research on sustainable business model archetypes, Bocken et al. (2014) have proposed different types of value proposition, creation & delivery and capture, depending on various business model archetypes. Particularly the archetype “deliver functionality, rather than ownership” is of great relevance here, as it lays out both the value and the expected environmental benefits of this approach.

Generally, it can be said that there is a growing body of research in PSS design and sustainability-related research which has begun to discuss the relevant aspects that particularly result-oriented business models bring about. However, the focus in terms of value is laid on the customer side, with the provider being seen as the facilitator of the value creation, or co-creation. The following subsection therefore discusses existing aspects that focus more or less explicitly on the value created for PSS providers.

2.3.3 A Provider-Focused Understanding of Value in PSS

The changes in the value created throughout the lifecycle of an offering, and thus the changing relationship between customer and provider, has been examined by Eggert et al. (2006). An explicit focus on the value attained by the provider through offering PSS is mostly missing in the literature. Of course, customer value-oriented approaches, such as Service Engineering (Sakao and Shimomura, 2007), customer value evaluation (Sakao and Lindahl, 2012) and value visualization for PSS (Bertoni et al., 2013) indirectly aim to enhance the provider’s market position, thus supporting the provider’s capability to capture value. Kowalkowski and Kindström (2009) discuss a value visualization concept, which enables providers to clearly communicate the value of their PSS for all of the lifecycle stages, thus also focusing on enhancing the value captured and therefore provider value in monetary terms.

Only recently, Pezzotta et al. (2014) discussed balancing customer value and “provider’s performance”, therefore displaying an explicit focus on the value attained by PSS providers throughout the entire life of the offering. However, the one-sided focus on the customer side of the co-creation of value that is a highly integrated PSS leaves a tremendous gap for optimization with respect to the provider side, offering the chance to attain considerable improvements in resource efficiency and new business opportunities.

2.4 Organizational Challenges and Internal Company Relationships

Making a transition from designing products and services separately to designing highly integrated PSS is challenging – and even more so since companies may not make a complete

transition but continue to offer traditional product sales. This has been described by Kowalkowski et al. (2015), where the authors question the notion of a transition from a product producer to a full-service provider, which would in the terminology used here be similar to the provider of a result-oriented PSS. The result is a dualism between the established sales and product-oriented principles.

The issues that most commonly occur are referred to as over-the-wall problems. Figure 3 illustrates the ideal situation when developing highly integrated PSS, a situation which is, at this point, of mostly academic nature. This challenge is one of the foci of the research presented here.

Figure 3 – Approach to product and service design in engineering design and highly integrated PSS

The reasons for a possible lack of cooperation and causes for continuing to operate similarly to traditional product sales are numerous. Already early in PSS research, Manzini (1999) pointed out a need for a changing corporate culture and a different organization. After concluding a long-term longitudinal study, Windahl (2007) pointed out a number of factors critical to successfully implementing integrated offerings for the first time. Among them was the creation of externally independent but internally integrated business units, to ensure a focus on the task while being able to reduce the existing path dependency in the established organization. Mont (2002b) pointed out that “the reorientation of companies towards PSS requires a fundamental shift in corporate culture [...]”.

Thus, companies offering highly integrated PSS which aim to perform efficiently need to be aware of a large number of requirements with respect to culture, structure and cooperation. The research included in this thesis was performed under an awareness that this corporate change is challenging and remains unrealized with many PSS providers. Regardless, the aim is to provide further arguments for an increased adaptation of companies to structures which are seen as favorable in order to design highly integrated PSS.

2.5 Building the Frame – The Interrelations between Different Elements

Within the presented theoretical framework, a diverse background for the research conducted was presented. This consists mainly of PSS and PSS design, as well as the concept of value in connection to this. Further, the aspect of organizational challenges and internal company relationships was introduced, with the main aim to offer an additional approach to explain and interpret the empirically identified effects. When reading this thesis consecutively, the connection between these elements may not be fully apparent at this time. This is justified by the fact that in the beginning of the research journey, the connections between these elements were no clearer than they are to the recipient at the end of this theoretical framework. Thus, the choice was made to not establish this discussion after the fact within the theoretical framework. Rather, the connection is clarified in the Discussion, particularly Section 7.3. Of course, the reader is given the freedom to read the respective section now, in order to approach the coming sections from a more informed point of view.

3. Methodology

This section introduces the scientific methods used in gathering and analyzing the results of this research. The general research approach as well as the methodical approach to answering the individual research questions is presented.

3.1 Research Approach

The aim of the research presented is *to develop a deeper understanding for PSS design as currently performed in industrial practice, to identify opportunities for facilitating the adoption of PSS design methods, and to examine the value that can be attained throughout the lifecycle by providers offering highly integrated PSS*. Here, the research approach directed towards attaining this aim will be detailed.

In an overall sense, this thesis employs an exploratory approach. Exploratory research is described by Patton (2002) as research in “[...] new fields of study where little work has been done, few definitive hypotheses exist and little is known about the nature of the phenomenon [...]”. This applies particularly to the area of value for PSS providers, where very little prior knowledge is present. Also with the focus on the current status of PSS design processes, an exploratory approach relying on different qualitative methods is deemed appropriate. A descriptive tendency in the research conducted only emerges with regard to understanding and utilizing existing knowledge on design methods, which in large parts relies on the existing literature in other fields and aims to synthesize information for providing lessons for the field of PSS design.

As introduced in Section 1.5.1, two companies are in focus with respect to the empirical gathering of data: Levor and Navitas. Within these companies, separate single-case investigations were carried out, utilizing highly adapted approaches with respect to the varying units of analysis (cf. Yin, 2013).

The research conducted did not follow a linear flow in accordance with the research questions. Rather, as indicated in Figure 4, different investigations were carried out simultaneously. Eventually, the results of the two main streams of research, which are reflected by the twofold aims as introduced above, are discussed in relation to one another in order to derive lessons going beyond the results of the individual research foci.

Figure 4 – Illustration of research approach and logic between different research foci.

In order to operationalize the exploratory research approach, a number of different qualitative methods were employed. In the following, the methods used to investigate each of the research questions stated will be presented.

RQ1: How have companies adapted their design processes to offering highly integrated Product-Service Systems?

This initial investigation was undertaken in order to answer a “how” question, which is an indicator for the applicability of an exploratory research approach (Yin, 2013). Only through understanding the status quo in industrial practice is it viable to provide meaningful and applicable input with respect to method development and design process adaptation. To achieve this end, investigations at both Levor and Navitas have been carried out. At Levor, the study consisted of a total of five workshops utilizing the actor mappings method in the frame of expert interviews (Meuser and Nagel, 2002) in order to understand interrelations between different stakeholders involved in the design of PSS offerings within the company. At Navitas, data was gathered through participant observation in meetings and workshops

(cf. Patton, 2002, 25 ff.), and the study of internal documents such as meeting minutes and process descriptions. In order to ensure the viability of the conclusions drawn, these were subsequently verified through the project lead, who was present at all of the instances where data was gathered. Through this broad approach, different aspects of current challenges with the adaptation of design methods to offering highly integrated PSS could be investigated simultaneously, leading to a reduction in depth but stronger breadth in the investigation. As the goal was to derive an overview of the current situation, this was deemed a viable approach.

RQ2: What are the potential means of facilitating improved PSS design through the implementation and use of PSS design methods in industrial practice?

The interrogative “what” points to an exploratory nature of the question (cf. Yin, 2013), while the strong focus on prior research points to the question’s descriptive nature. The main effort in answering this question is dedicated to a literature review on fields associated with PSS that have experienced similar struggles with method implementation and design process adaptation. Through understanding lessons and outcomes of research with a similar trajectory in another field, the goal is to simplify and shorten the process of deriving practically and academically useful information for the area of PSS. How the findings relate to the core field of PSS design was then elaborated on through a questionnaire with industry practitioners at Navitas, who had more than two years of experience in the trial of a PSS design method at that company. As a result of the questionnaire and the literature study, normative recommendations for the future design of PSS design methods were derived.

RQ3: How can the value attained by providers throughout the PSS lifecycle be characterized?

The topic of value for PSS providers is largely undiscussed in the literature, and its relevance to the topics of designing and offering PSS has not been previously investigated (cf. Yin, 2013). In order to structure the data collection, a number of methods, of which some were solely conceived for this purpose, were employed. This was further warranted by the exploratory nature of this study and the high level of uncertainty involved when venturing into a new research direction, as was the case here. The literature discusses different types of interviews, e.g. open, semi-structured and expert interviews (Flick, 2009). In order to be able to structure and facilitate the data collection, in addition to conducting expert interviews (see e.g. Meuser and Nagel, 2002 as cited in Flick, 2009), these interviews were supported by a structured data collection approach termed “Provider Value Analysis (PVA)”. Through this approach, some of the inherent uncertainty of the topic of investigation could be reduced while at the same time improving the reliability, documentation and scientific soundness of the study (cf. Flick, 2009). PVA in expert interviews was used to gather initial information on value for providers from practitioners working with highly integrated as well as product-

oriented offerings in the use phase of the lifecycle. The efforts resulted in a conceptualization of value for PSS providers, which is based partly on existing research on the topic of value, but mainly on the results of the PVA-supported expert interviews conducted at Levor.

RQ4: How can the understanding of the providers’ value of offering highly integrated PSS be operationalized for applicability in the PSS design process?

In a continuation of the methodical approach taken towards answering RQ3, the study at Levor was continued with expert interviews. These interviews were supported by a structured data collection sheet as well as the ProVa method (see Section 3.2.6). Again, the research had an exploratory orientation (cf. Patton, 2002; Yin, 2013). The value concept was used to structure the collection of data and to support the practitioners in following, extending and applying the understanding derived as a result of RQ3. Again, the goal was to ensure comparability of the outcomes of the data collection efforts with different practitioners, and thus to improve the reliability, generalizability and scientific soundness of the results (cf. Flick, 2009). To take account of the understanding of the respondents with respect to the concept of value in advance of the interview, all respondents completed a web-based questionnaire up to three days prior.

3.2 Research Methods

This subsection introduces the methods that were used to gather and interpret information throughout the entire research process in detail. In order to provide an overview over which methods were used in which of the appended papers, Table 1 assembles all of this information in a condensed fashion. With respect to the literature reviews conducted, the small indication for Paper 3 signifies the lower importance of the literature review for this work.

Table 1 – Overview of the relation between individual papers and methods used

Paper/Method	Literature			Actor		
	Review	Questionnaire	Observation	Maps	PVA	ProVa
Paper 1 – PSS Design Status Quo	X		X	X		
Paper 2 – PSS Design Methods	X	X				
Paper 3 – ProVa Method	x					X
Paper 4 – Provider Value	X	X			X	X

3.2.1 Literature Reviews

Literature reviews were conducted throughout the entire length of the study, each with a differing extent and focus. For the most part, the goal of the reviews performed was to “bring focus to the study” (Patton, 2002) and to understand the background of a particular topic at hand.

Initial review

An initial review, was conducted to arrive at a broad overview of the field of PSS and other relevant areas (IPSO, Functional Sales etc.), engineering design, and engineering design methodology. This review was begun before the start of this research due to the similar focus of previously conducted student work. The review was extended continuously throughout the research process and in accordance with the requirements as the work progressed. With respect to Patton's (2002) differentiation, this initial review is to be considered as a broad review. Due to the extensive time frame of this search, a vast amount of literature was scanned, diving deeper in case relevant information was discerned (cf. Yin, 2013). Using categorization-options, scientific work deemed interesting was catalogued using the Mendeley reference management software, including saving the PDF files if available. As the Mendeley software allows searches directly in the full-text PDFs and based on the set categorization, this approach provided an efficient basis for future searches during the paper writing process. This is due to the fact that it made repeated extensive searches in web-based engines, including skimming a mass of irrelevant information, almost unnecessary. A disadvantage of this can be that new knowledge can be overlooked by relying on a local database. In order to avoid this, the suggestion features of Google Scholar and Mendeley, which are based on interest and existing citations, were used. Further, the functions of scientific search engines such as Scopus or Science Direct, which suggest relevant papers to the ones one is currently reading, was extensively used to get a broader, although random, overview of the field. In addition, for each of the papers, a dedicated, depth-oriented literature search was performed (Patton, 2002), which is described hereafter.

Individual, depth-focused reviews

With respect to Papers 1 and 2, the general review was deepened with a strong focus on methodical design processes in the fields of engineering design, Ecodesign and PSS. Here, to begin with, a keyword-based search was performed, with very overall search terms such as PSS, IPSE, IPS², design, design methods, method adoption and so on. During this keyword-based search, the Scopus engine was used and results were initially restricted to the relevant fields to narrow down the results. Subsequently, paper titles were checked and relevant results selected. Thereafter, abstracts were skimmed for relevance. Then, the papers were added to the personal Mendeley catalog, including the needed meta-information. After concluding

this gathering of information, detailed reviews and searches were performed with the saved documents. In addition, in the case of Paper 2, a citation-oriented approach was taken: Lindahl (2005) compiled extensive information on the use of methods in Ecodesign. Lindahl (2005) was examined with focus on major references. It was then studied which works referenced Lindahl's main sources in the parts relevant to the focus of Paper 2 after its publication date. This gives a concise yet comprehensive overview of the developments in the area in the last decade. In addition, other references from these papers and their citations were taken into account, spreading the scope of the literature in a tree diagram fashion.

With regard to Papers 3 and 4, the scope of the search was focused on the topic of value in both a broad and narrow sense. Initially, with respect to paper 3, a review focused on the concept of value only in the area of PSS was performed. The result was a small set of literature, which was seen as an indication of the newness of the direction taken with the exploratory research (Yin, 2013) – a notion which was reflected and verified by the attendants of the conference presentation. With the goal of moving forward with the conceptualization of value as a relevant concept for PSS providers and designers, the literature review was both extended (to the research fields of relationship management, marketing and service-marketing/management, and servitization) and deepened (with respect to the value concept as such). There, a keyword-based search was attempted, which led to an extremely broad set of results, as the research field is mature and widely covered by a substantial number of researchers. Thus, in order to narrow down the scope and to achieve a sufficient and relevant understanding, a focus on recent and highly cited papers was set. In the field, the paradigm-shifting paper by Vargo and Lusch (2004) is highly regarded and cited. In checking papers citing this work, a good view for recent developments on the question of value in service marketing and adjacent fields was acquired, which resulted in the value-focused theoretical framework as presented in Section 2.3. The references used in Panarotto (2015), for example, which represent further value-focused PSS work, reflect the applicability and relevance of the sources found – although admittedly some cross-pollination between this and similar works and the research presented here cannot be ruled out.

3.2.2 Questionnaires

Questionnaires were used in order to gather data in a concise fashion, without affecting the actual interview process: As Flick (2009) states, “[a] questionnaire will allow you to collect the data [...], which [is] less relevant than the topics of the interview itself before the actual interview”. Since in both cases, when the questionnaire method was used, the focus of the questionnaire was not the core focus of the interview/meeting, this was deemed to be an appropriate approach.

Method properties questionnaire

In order to understand the applicability of challenges in engineering design methods to PSS design, part of an otherwise confidential questionnaire used at Navitas was dedicated to this. Seven factors relevant to the implementation of PSS design methods were rated by participants on a five-point Likert-type scale. This was a viable, fast and simple approach to gathering important information from practitioners as part of a larger internal meeting, in which two LiU researchers participated and which had a different focus.

Understanding the viability of a provider-focused value concept for use in design and development

In this, the questionnaire method was used to take account of the respondents' understanding of value prior to the interview. Here, this approach was taken to adjust the focus of the actual interview according to the prior knowledge of the respondents, and therefore to ensure an efficient interview process. The questionnaire was sent to each participant three days in advance of the interview.

3.2.3 Participant Observation

As defined by Denzin (1989) and cited in Flick (2009), a participant observation is “[...] defined as a field strategy that simultaneously combines document analysis, interviewing of respondents and informants, direct participation and observation [...]”. In the study at Navitas, which led to a part of the results presented in Paper 1, all of the above-mentioned activities were performed over an extended time frame within a project aiming to trial a PSS design method for implementation into existing design processes. Although the level of participation was lower than the extent discussed by Flick (2009), the presence at many internal meetings and workshops may have led to a slight influence on the actual information eventually attained. In order to limit this effect, all results presented were confirmed by the internal project lead at Navitas at the conclusion of the project. The approach taken to gather information included scrutinizing a large number of internal documents focused on the current design process and other internal procedures, and discussions and participation in a number of meetings (with outcomes documented and confirmed in minutes). Because of the regularity and depth of these events, a substantial understanding for the challenges perceived by the projects' participants was attained, which is of general value in an aim to comprehend the process of implementing PSS design methods and adapting existing processes.

3.2.4 Actor and System Mapping Workshops

Offering highly integrated PSS is a substantial challenge for companies previously focused on selling products. In order to understand this challenge, it is important to comprehend the relationships between different actors (whether individuals, groups or organizations). Get-

ting this understanding directly from practitioners is vital, as the true processes and connections often deviate substantially from the picture organizational charts aim to convey. Therefore, the approach first introduced in (Lindahl et al., 2014a) and further extended and refined in (Desai et al., In Press) was utilized. Based on the individual work situation, participants were asked to elaborate upon the way they work with integrated offerings, how information is exchanged and shared and how the entire process is organized. Using different colors, actors and the information exchanged by them were drawn on a whiteboard, being extended and adjusted throughout the length of the workshop. The results were then digitalized using Microsoft’s Visio software.

3.2.5 Provider Value Analysis (PVA) in an Expert Interview

As the concept of the value attained by PSS providers is novel and difficult to convey to the interviewees, and in the view of the limited number of interview hours available, a method supporting the data gathering process was developed and applied. The approach of using a dedicated and tailor-made method was further intended to facilitate the data gathering, to increase the comparability of the results and to enable the derivation of a common concept based on the different responses attained. Figure 5 shows a mockup of the data-gathering sheet which was used. This was done in paper format on one A3 sheet.

	Value Dimension				Value Dimension				Overall Assessment				Essential Value-Dimension for this Component	
	Customer		Provider		Customer		Provider		Customer		Provider		Customer	Provider
	PSS	Sales	PSS	Sales	PSS	Sales	PSS	Sales	PSS	Sales	PSS	Sales		
Provider’s Activity/ Physical Components	+	+	+	+	+	+	+	+	+	+	+	+		
	0	0	0	0	0	0	0	0	0	0	0	0		
	-	-	-	-	-	-	-	-	-	-	-	-		
Provider’s Activity/ Physical Components	+	+	+	+	+	+	+	+	+	+	+	+		
	0	0	0	0	0	0	0	0	0	0	0	0		
	-	-	-	-	-	-	-	-	-	-	-	-		
Importance of Value for Customer or Provider	H	M	L	H	M	L	H	M	L	H	M	L		

Figure 5 – Mockup of data gathering document for Provider Value Analysis

The approach used at Levor also gathered information on customer value, which at this point is only for internal use at the company. The necessary information was gathered completing the following steps with each participant:

1. The interviewee was asked to elaborate on the ways s/he creates value for customers in the daily working tasks that are performed. As the interviewees elaborated, the two interviewers took notes and at times asked follow-up questions.

2. The most interesting and relevant aspects were selected by the interviewees in Step 2. These aspects constitute the value dimensions as shown in Figure 5.
3. The interviewees were asked to rate the importance of each of the items mentioned separately for aspects relevant to customers as well as providers on the levels of (H)igh, (M)edium and (L)ow. This was done separately for both product-oriented and highly integrated PSS offerings.
4. In order to support future efforts in a component-oriented evaluation, interviewees are asked to name physical components or activities/services that generally contribute to the generation of the value identified in Steps 1 and 2.
5. To understand the impact of the components and activities/services identified in Step 4 on the values found in Step 2, the interviewees were asked to evaluate this impact on the following scale: Does not apply (no connection between value and components/activities/services), Positive (component/activity/service contributes positively to value, +), Neutral (no impact on value, 0), and Negative (decreases the value, -).

As a result of using PVA, the following information was attained in a comparable fashion from all participants:

- Dimensions relevant for value attained by providers both in cases of highly integrated PSS and product-oriented items. These are necessary to facilitate a future value-focused design evaluation.
- Importance of the identified dimensions.
- Relation between components, services/activities and the identified dimensions.

In analyzing and generalizing the PVA results, the following approach was taken: As detailed by Lillis (1999), the meaningful analysis of data collected by [expert] interviews is challenging. For the parts of the data gathering relevant to deriving overarching value determinants (mainly Steps 1 and 2 of the method detailed above), a clustering approach (or, for that matter, subsuming particulars into generals) as indicated by Miles et al. (2013), has been applied. As the clustering effort in this particular case is directly related to the research aim and controlled by prior research, it can be seen as non-arbitrary in accordance with Miles et al.'s (2013) description and is therefore worthwhile in order to attempt a generalization for a greater usefulness of the results.

To perform a relevant clustering, the interviewers' notes as well as the data gathering sheet and the respective parts of the interview recordings, usually the first 15-20 minutes, were revisited. All of the mentioned value determinants were laid out on paper. As a first step, identical or near-identical mentions were clustered and unified under the most general determinant. From an initial number of 41 determinants, this rendered a number of 28 after

the first stage of clustering. Subsequently, semantically or contextually related items were marked and connected by lines. Lastly, the assembled clusters were noted and headings describing the content were sought, while providing a clear account of this process in the respective Paper 4.

3.2.6 Provider Value Evaluation (ProVa)

Proposed as a method for the evaluation of the expected value delivered to providers throughout the lifecycle of a highly integrated PSS through components, services and activities, ProVa was developed and presented as a result of Paper 3. Figure 6 shows the steps of the method, which are elaborated upon in detail in the respective paper. As further clarified in Paper 3, the process may benefit from iterative use, which takes advantage of information and experience gathered in prior method executions.

In the study at Levor, ProVa was used as a basis for discussing the possible operationalization of the value concept with a provider focus, and to facilitate an understanding of value for practitioners involved in product and service design within Levor, a provider of highly integrated PSS. Further, the viability of using ProVa both during the PSS design process and as a one-off learning tool in the future was evaluated.

Figure 6 – Process of Provider Value Evaluation method (ProVa, Matschewsky et al., 2015b)

3.3 Reflecting upon Research Journey and Methods

At the beginning of the work leading to the research presented here, there was little clarity about the overall aim and goal of the research. This led to an initially quite unstructured approach toward the central questions discussed here. An example of this is the development of an initial version of the ProVa method early on in the research, as there was a focus on operationalization and making the understanding of the provider's value available in a form that would be appreciated by academics and practitioners alike. Only later was it understood that a more refined and substantiated approach towards the value concept was needed for the assessment to be viable and useful. Thus, empirical efforts were undertaken, which eventually also led to a revisit and increased understanding of the ProVa method and its improvement possibilities. The inefficiency of this research journey with a number of feedback loops between different stages of the work conducted marked its early phase in particular. Over time, and as a result of a large number of contacts with industry practitioners, patterns began to emerge, and increasingly, the focus of the research became clearer. As a result, the methodical approach towards data gathering and analysis was refined and structured, and the voids left by premature efforts were filled with the required information.

Due to the complexity of the research, a multitude of methods, some of them newly conceived just for this purpose, were used. As these methods are previously untested at this point in time, their viability and usefulness can be disputed. However, since the new means of gathering data, particularly the Provider Value Analysis data-gathering sheet, were used in the context of an established qualitative method and only intended as a support and facilitator, it can be expected that this had no negative effects on the soundness of the acquired data.

4. Contributions and Summaries of the Appended Papers

This section introduces the content of the appended papers in a brief fashion. This is done in order to facilitate the understanding of the results presented and discussed in the coming sections.

4.1 Connection between Papers and Research Questions

Table 2 aims to clarify the link between the research questions introduced in Section 1.4 and the appended papers. While such a reduced visualization cannot convey the contributions in their entirety, they do point to the most relevant papers with respect to each of the particular research questions.

Table 2 – Contribution of the papers to the respective research questions. The capital X indicates a major contribution of the paper, while the lower-case X points to a notable, while not major, contribution.

	Paper 1	Paper 2	Paper 3	Paper 4
RQ 1 – PSS Design Status Quo	X			
RQ2 – Method Implementation	X	X		x
RQ3 – Value for PSS Providers			x	X
RQ4 – Value Operationalization			X	x

4.2 Paper 1 – PSS without PSS Design – Possible Causes, Effects and Solutions

Author’s contribution

Sole author; co-supervisor provided feedback on the manuscript before the initial submission.

Aim

The research motivation for this paper was the apparent lack of adaptation of the design processes of two case companies to the new requirements brought about by offering PSS. Therefore, a deeper evaluation of the current design procedures and the causes for why they are set up in certain ways was conducted. This investigation had the goal to “to *examine* possible *causes* for the lack of process adaptation and method adoption with respect to PSS, to *clarify* the *effects* of this non-transition and to point out viable *first* steps aimed at *improving* this situation.”

Method

In order to investigate the complex topic of this paper, a set of methods was used. The theoretical framework was based on a previously conducted literature review on PSS design methods, while the review was extended with a focus on the individual items discussed in the paper, e.g. organizational challenges and information exchange. In the case of one case company, actor mapping workshops were conducted to understand and display the internal relationships between the design department and other relevant parts of the organization. With a further company, knowledge attained over an extended time frame was gathered through participant observation.

Contributions

In accordance with the title, the paper makes a contribution to three aspects of the lacking adaptation of design processes to PSS. As causes, the following issues were identified:

- Reduced customer pressure for constant improvement due to a changing incentive structure in the case of highly integrated PSS, which is not met by the necessary changes within the company in order to drive developments further internally.
- Stakeholders with a strong interest in well-designed and highly efficient PSS are not to a sufficient extent involved in the PSS design processes.
- Managers have not fully understood the consequences of offering PSS and thus, support for an effective process adaptation in the design process is lacking.

As a result of these shortfalls, challenges in both business and environment related matters were identified. With regard to business, mainly lost value creation opportunities were discussed. For environmental aspects, the problem of not utilizing the opportunities of substantially improved efficiency through a true lifecycle perspective was elaborated on. With respect to possible solutions, efforts for a true integration of the affected division within the companies were recommended.

Overall, Paper 1 delivers an essential understanding of the current challenges in the adaptation of design processes to PSS as well as an understanding of possible ways forward.

4.3 Paper 2 – Facilitating Industrial Adoption of Design Methods for Product-Service Systems

Author's contribution

Mainly written by the first author. Co-authors provided guidance and feedback during the research process, data gathering, paper writing and extensive revision after review.

Aim

This paper investigates the apparent lack of PSS design method adoption in the face of an abundance of academically created methods from the method point of view. Therefore, the

aim of the paper is to “identify general method characteristics that may improve implementability and usability of PSS design methods.”

Method

To form the basis of the research, a broad literature review was conducted in the field of PSS design. In addition, literature in adjacent fields, such as Ecodesign and engineering design, was investigated. In addition, a questionnaire with industry practitioners was administered, in order to evaluate the importance of different properties related to method implementation in industry.

Contributions

Paper 2 contributes in various aspects to the goal of improving the implementability and usability of PSS design methods, particularly those designed by academics. Namely, the contributions consist of:

- Gathering of industrial adoption promoters for PSS design methods found in the literature.
- Evaluation of the importance of critical factors that have an impact on the implementation and use of PSS design methods by industrial practitioners.
- General guidelines and six characteristics aimed to improve implementability and usability of PSS design methods.
- First steps towards an operationalization of the identified characteristics to be used by researchers and others developing PSS design methods.

In summary, Paper 2 contributes by structuring prior knowledge and providing insights that may be helpful with respect to PSS design through synthesizing and elevating these findings.

4.4 Paper 3 – ProVa – Provider Value Evaluation for Integrated Product Service Offerings

Author’s contribution

Initial draft mainly based on Matschewsky (2012), written by second author with support from first author, later extended and adapted by first author with guidance and feedback from all co-authors.

Aim

Based on Matschewsky (2012), this paper constituted the first venture towards a provider oriented understanding of the value of offering PSS. In that, the “objective of this paper is to introduce the concept of Provider Value (PV) for [PSS] and to operationalize this concept through the ProVa method for the PV evaluation of product- and service components of IPSO during the development process.”

Method

Based on a review of PSS-related literature, the concept of Provider Value as well as a classification for this value was developed. A stepwise method was derived for the assessment of this value on a component basis, in part based on cost-utility analysis by Zangemeister (1976). The method was applied to an industry-related case in order to show its effectiveness in different scenarios.

Contributions

Laying the groundwork for the concept of a provider-oriented understanding of value in PSS, Paper 3 has contributed in the following ways:

- A first discussion of the concept of provider's value in offering PSS.
- A first categorization of provider's value based on relevant literature, which serves as a measuring stick for future, empirically-gathered data.
- Introduction of a component-oriented evaluation method for value delivered to the provider throughout the life of the offering.
Case application, which shows the evaluation process and use of the method.

Overall, Paper 3 provides the point of departure for the research on both the provider's value in offering PSS and applied, method-focused considerations. Although the resulting method is also utilized in Paper 4, the knowledge going beyond the ProVa method and the understanding of its development make this paper an important element of this research.

4.5 Paper 4 – Capturing and Enhancing Provider Benefits in Product-Service Systems – A Systematic, Design-Centered Approach

Author's contribution

Manuscript written by author, partially based on an earlier draft written together with the supervisors of this thesis.

Aim

Paper 4 is focused on deepening the understanding of the value attained by PSS providers and utilizing this understanding in order to improve the design and therefore future performance¹⁰ of highly integrated PSS offerings. To achieve this, critical value dimensions were identified from practitioners in the use phase of the offerings, while these dimensions were subsequently evaluated for their suitability for use in the design phase by practitioners active there.

¹⁰ Both in an economic as well as in an environmental sense.

Method

Because of the broad range covered in this paper, a number of methods were utilized to acquire, synthesize and interpret the information. As a starting point, a broad literature review on the topic of value was conducted. Data was gathered in interviews with industry practitioners, which were supported by a novel structured method designed to gather data on value in PSS called Provider Value Analysis. The qualitative data gathered was analyzed using qualitative methods (e.g. clustering). The applicability of the gathered information to support value-driven PSS design and to operationalize the value concept in an industrial environment was assessed through questionnaires and expert interviews, partly supported by the ProVa method introduced in Paper 3.

Contributions

Paper 4 contributes to the understanding of the value and its possible impact on industrial practice with respect to designing and offering PSS. The following contributions can be noted as a result of the paper:

- A deeper and empirically-supported understanding of the value attained by providers offering PSS during the use phase of the offering.
- Insight on the applicability of this understanding for the assessment of the expected value of PSS offerings in the design phase.
- A conception of the usefulness of a dedicated evaluation approach for the provider's value for R&D, design evaluation as well as to foster a deeper understanding of value in PSS in contrast to product sales.

Paper 4 utilizes parts of the information gathered in previous publications and contributes with extended knowledge to both the value concept for PSS, its operationalization and the effect that can be expected from its use in industry.

5. Exploring the Status Quo – PSS Design Processes and Methods

This section presents the results of the research conducted with a focus on PSS design processes and methods.

5.1 Inherent Challenges of PSS Design Methods

Both prior research and the interactions with a number of industrial PSS providers have shown that the adoption rate of specifically designed PSS design methods is low (see Baines et al., 2007). There is a multitude of causes contributing to this situation, which lie with the methods themselves as well as the companies offering PSS. This subsection elaborates upon these causes from different viewpoints, resulting from research presented in Papers 1 and 2.

Here, the results of the research conducted on the status quo of the challenges with implementation and use of PSS design methods are first discussed. Recently, the assertion has been made that the lack of fitting methods may play a role in a lacking adoption of the PSS business model (Hänsch Beuren et al., 2013). Now, under the assumption that the methods themselves are part of the issue, the question must be asked: What can be done to alleviate the situation?

In this subsection, the focus lies exclusively with the issue of the design methods, and less with the general challenges of implementing an integrative approach to jointly offering products and services.

5.1.1 Learning from Others: Engineering Design and Ecodesign

As an initial step, the lessons of prior research with respect to the actual challenges around the adoption and use of design methods were scrutinized. Since this research was lacking in the immediate field of PSS design research, adjacent fields such as engineering design and, with even stronger focus, Ecodesign, were examined. These fields experienced and continue to experience similar challenges when compared with PSS design (Andreasen, 2011; Lindahl, 2005). By applying the findings in these fields and evaluating possible overlaps with the area of PSS, findings were produced with the intent of supporting the adjustment and development of methods for PSS design without the need for extensive empirical work – as this was already available from the aforementioned related research fields.

5.1.2 The Value of Methods

Specifically designed methods have been found to support companies, generally speaking, in two different ways (Daalhuizen, 2014): They can either be seen as aids to the skill development for engineers (Schön, 1983) and therefore as learning tools, or they can be understood as best practices, increasing the reliability with which certain outcomes are achieved (Simon, 1969). It is further evident that methods are not an end in themselves and carry little value if they cannot be efficiently applied to a practical problem (Andreasen, 2011).

A number of researchers have pointed out the need for specific methods to be designed for PSS (cf. Hänsch Beuren et al., 2013; Morelli, 2006; Wolfenstetter et al., 2015); their development is even regarded as an indicator for the maturity of the research field (Tukker, 2015).

5.1.3 Challenges for Method Adoption across Engineering Design, Ecodesign and PSS Design

In prior research, a number of challenges to method adoption and adaptation have been found and discussed. Table 3 assembles and categorizes these challenges into a concise overview.

Table 3 – Challenges for method adoption as identified in the literature

Category	Challenge	References
Time	Time-consuming processes	(Lopez-Mesa, 2006; López-Mesa and Thompson, 2006)
	Workshop-style methods, as they are perceived as time-consuming and unfit for day-to-day practice	(Lofthouse, 2006)
Formatting	Methods are ill-formatted for company use: Lengthy descriptions, overly theoretical approaches	(Geis et al., 2008; Jänsch and Birkhofer, 2007; López-Mesa and Thompson, 2006; O’Hare, 2010)
Scope	Decision-making under uncertainty: Lack of trust in results of weighing and rating efforts	(López-Mesa and Thompson, 2006)
	Excessively detailed or broad approaches; specific vs. strategy-oriented approaches	(Birch et al., 2012; Tukker, 2015; Vasantha et al., 2012)
	Ability to handle low-quality data	(Lofthouse, 2006)
Adaptability	Fit of methods with established processes	(Knight and Jenkins, 2009)
	Degree of adaptability and customization conveyed	(Geis et al., 2008; Le Pochat et al., 2007)

In order to examine the relevance of these aspects, a questionnaire was performed with seven practitioners involved in the trial of a PSS design method and design process adaptation at Navitas. This background lends credibility to the assumption that the respondents have extensive knowledge on the challenges of offering PSS, implementing design methods and the adaptation of design approaches, particularly in the context of such a large company. Table 4 shows the results of the questionnaire.

Table 4 – Results of evaluation of influential method properties with respect to implementation, (Matschewsky et al., 2015a)

Influential properties for implementation	Importance					Avg	Med
	1	2	3	4	5		
Time required to use the method			2	1	4	4.3	5
Format and presentation of the method (e.g. forms, software, etc.)			1	4	1	4.0	4
Compatibility of the entire method with the established processes		1	1	4	1	3.7	4
Customizability/flexibility of the method to be adapted to processes			2	2	2	4	4
Availability of information with sufficient quality required for decision-making in using the method				4	2	4.3	4
Capability of decision-making under uncertainty when evaluating		1	2	3	1	3.6	4
Level of collaborative efforts required to use the method across the company	1	1	2		3	3.4	3

Resulting from this assessment, the relevance of different aspects identified in non-PSS-focused literature is substantiated with respect to PSS design and its inherent challenges. Based on this understanding of existing challenges, a framework of guidelines was developed to assist with the design of generally applicable methods which are apt to support and facilitate a higher and higher quality adoption of the PSS business model – in hopes of incurring the intended benefits for all stakeholders involved. This is shown below in Section 7.1.2.

5.2 Offering PSS vs. Designing PSS: Crucial Differences

The studies forming the basis of the results presented here investigated the discrepancy between the Levor's and Navitas' apparent success in offering and marketing PSS offerings, while the impression prevails that a comprehensive adjustment of design processes and approaches has not taken place. Overall, a number of possible causes for this situation have been identified. They are introduced in brief below:

5.2.1 Customer Pressure and Understanding Changed Incentives

In synthesizing information attained at Levor as well as conceptual literature on PSS (cf. Baines et al., 2007; Meier et al., 2010; Vezzoli et al., 2015), a substantial change was discerned which appears to not yet have found its reflection in Levor's design processes and general understanding of its offerings. Figure 7 illustrates this relationship.

Figure 7 – Changes in incentives comparing product sales to highly integrated PSS, (adapted from Matschewsky, In Press)

As Figure 7 conveys, the incentives for customers and providers with respect to operational efficiency¹¹ in the case of product sales is clear: Cost reductions as a result of efficiency-improvements end up being a benefit to the customer and therefore constitute customer value¹², along with assumed environmental improvements. Thus, customers set requirements for improved efficiency and therefore drive this aspect of the performance of a product sales offering forward (as is conveyed in dark blue in Figure 7).

When offering physical products as a part of highly integrated PSS, the incentives for customers and providers change substantially. As a side effect of the opportunity to focus on core business, which highly integrated PSS provide, customers focus largely on effectiveness, i.e. a task performed according to specification, and less on the efficiency of achieving this end. This reduced customer pressure with respect to use phase efficiency is, in turn, not internalized sufficiently by Levor. Resulting from this, the opportunities indicated in Figure 7 (green color) are not realized. Since different company divisions become each other's customers in

¹¹ Examples of this are lower energy use during operation or longer maintenance cycles.

¹² Shown as CV in Figure 7.

case PSS are offered, efficiency requirements should be owned by internal divisions instead of external customers. As these changed relationships are a challenge to discern even by practitioners active in the company (as shown previously in Lindahl et al., 2014a), the need to adapt existing design processes to the new structure of requirements is not perceived strongly by PSS providers. This situation is exacerbated by Levor's technological aptitude to fulfill the effectiveness-related requirements of customers.

5.2.2 The Unheard Voice of Internal Stakeholders that are Key to PSS Design

Lean engineering has had a substantial impact on the manufacturing industry because of its strong focus on the cooperation of different divisions within manufacturing companies, not least during the design process (Dankbaar, 1997). Levor is a company strongly invested in the concept of lean. Under the hypothesis that the focus on internal cooperation can only be exacerbated by offering PSS (Martinez et al., 2010), actor mapping workshops were conducted with five professionals involved in design at Levor in order to understand existing internal information flows between different actors involved in the design process. Since strong relevance is assigned to information from service/maintenance as well as remanufacturing divisions with respect to information feedback and use of PSS design methods (see Aurich et al., 2006; Lindkvist, 2014; Sakao and Mizuyama, 2014; Sundin et al., 2009, 2008), they were of particular interest in the study.

As a result of the studies conducted, it became clear that neither the knowledge acquired by service technicians nor the remanufacturing division was utilized to a notable extent in the design process. Due to this lacking influence of stakeholders benefitting from excellent PSS design, the pressure perceived by decision makers to adapt existing processes is reduced and design and development continues in the established lanes.

5.2.3 Managerial Focus and a Dominating Product-View

In the course of an extensive project, a PSS design method (SPIPS¹³, as published in Sakao et al., 2009) was trialed at Navitas. The results presented are the synthesis of many meetings, interviews and workshops over the course of the project.

The challenges of starting to bring integrated offerings to market have been discussed previously, particularly in research focused on the business and marketing aspects of PSS. In an extensive study on integrated solutions in the capital goods sector, Windahl, (2007) makes the following statement directed towards companies intent on offering integrated solutions: "Create independent business units to get focus while still maintaining strong links to [the]

¹³ Customer-Oriented Solution Provider – through Integrated Product and Service Development, an extensive method focused on cooperation, utilizing an adapted Quality Function Deployment (Akao, 2004) approach in order to take account of substantially changed requirements with highly integrated PSS.

line organization – top management support needed”. Nonetheless, Navitas attempted a trial of product-service integration and process adaptation integrated in the existing, product-only-focused line organization. From this approach, a number of challenges emerged, which did not impede the company offering highly integrated PSS. They did, however, hamper process adaptation and may reduce the efficiency of the offerings provided to customers.

Overall, the most substantial challenge was posed by the strong organizational separation of the product design and service design divisions and the relationship of the divisions. Naturally, Navitas had and still has a strong product focus with priority given to excellent engineering solutions. Service development was performed at the end of the product development and cooperation between the product and service divisions was a challenge, as it was further hampered by the presence of a market-oriented organization mediating between these divisions. Further, as a result of the substantial differences in size between the divisions, the product side had little incentive to actively cooperate in the implementation of the proposed (or any other) design approach for integrated offerings. A central aspect to this was the success of the current product sales offerings, and thus very little pressure to adapt was felt by the managers involved. As a result, managerial support for the proposed approach was weak with product-focused management personnel, while service managers felt a strong need for adaptation. The complexity and extensiveness of the proposed method was a challenge that was strongly perceived by the project’s participants (see Section 5.1.3). This undeniably further hampered the implementation efforts.

6. Shaping an Understanding for the Provider's Value in Offering PSS

This section presents the results of the research conducted with a focus on the value attained by PSS providers, as well as possible means of its characterization.

6.1 Introduction

The research focused on value for PSS providers has led to results in different aspects: An initial conception, for example, resulted from a literature study. Subsequently, through a series of empirical inquiries, a more coherent and practically applicable understanding was derived. This, in turn, led to the continued development of an approach towards the evaluation and enhancement of component and service parameters relevant to the provider's value in offering PSS. This approach was then evaluated in a series of workshops for applicability, usability and other learning effects as experienced by the participants. This section details the results with regard to all of these aspects in a concise fashion.

6.2 Initial Hypothesis for Provider's Value

Departing from the widespread conception of customer value in the PSS literature (see Kimita et al., 2009b; Sakao and Lindahl, 2012; Shimomura et al., 2009), the apparent omission of a multidimensional approach towards the value attained by the providers of PSS appeared as a worthwhile research trajectory. When comparing product sales and highly integrated PSS, the extended relationship between customer and provider gives rise to new value creation opportunities. Carrying out services at the customers' facilities provides value to the customers, while it offers the provider the possibility of attaining additional, less tangible and hard-to-measure value in the course of the service provision: Information can be attained, and strengthened customer relations are seen as critical aspects of PSS provision (Sakao et al., 2008). The value attained for providers is considered to diverge not only in the scope of service provision from that in product sales; with a focus on physical components of PSS, the way providers attain value is also changed. Due to ownership changes and the longevity of the customer provider relationship, including components that do not directly contribute to revenue generation could still be worthwhile.

In order to be able to approach the concept of value for a provider beyond the aspect of directly obtained monetary value, a classification presented in Paper 3 was formulated based on the literature. This initial classification consisted of the five dimensions environment, customer relations, information, infrastructure and time to market. The approach resulted in an easier understanding of the new conceptualization, although lacking depth and practical substantiation, which were provided by future research efforts.

6.3 An Industry-Supported Understanding of Value for PSS Providers

In highly integrated PSS, value for the provider is created throughout the use phase of the offering, and even beyond that. In order to understand this value creation and its extent, meaning and differentiation from the value obtained through traditional product sales, information was gathered from practitioners working with the offerings in the use phase.

6.3.1 Exploring Multidimensionality in Value for Providers

In order to take into account the current understanding of the value attained by PSS providers through their offerings, workshops performing Provider Value Analysis were held with seven practitioners. A value-oriented thinking was induced through the exploratory approach detailed in Section 3.2.5. A number of value dimensions were identified, ranging from four to eight dimensions per practitioner. Table 5 shows all of the different value dimensions identified through the participating practitioners with the respective importance for the provider side.

Table 5 – Identified value dimensions with the importance for the providers as assigned by the practitioners

Sales Personnel		Service Personnel	
Value Dimension	Importance	Value Dimension	Importance
Financing	High	Cost Forecasting	High
Freedom (Risk Sharing, etc.)	High	Well-designed product	High
Economy (Monetary Value)	Medium	Security and Continuity	High
Quality	High	Environment	High
Ergonomics	Medium/Low	Increased Competence	High
Safety	High	Technicians' Knowledge	High
Long-Term Thinking	High	Effective Service	High
Innovativeness	High	Simplified Communication	High
Information	High	Higher Availability	High
Experience/Knowledge	High	Quick Response	High
Customer Specifications	High	Customer Relations	High/Medium
Customization	High	Backup (Personnel)	High
Capacity	High	Packaged Solution	High
Partnership	High	Brand	High

In analyzing these results, evaluation clusters were formed as detailed in Section 7.2.2. These clusters, together with the value dimensions named by Levor personnel, were used in the ongoing research with practitioners working in areas associated with the design phase at Levor. Therefore, the following subsection partly relies on these clustered value dimensions.

6.4 Exploring the Relevance of Provider-Centered Value on PSS Design

In order to explore the possible impact of a differentiated value concept with a strong provider focus in the design of PSS, a number of empirical investigations were performed. On the one hand, the goal was to understand the implications of applying provider-centered value considerations in the PSS design process, and on the other, to move towards a possible operationalization of such an approach. For this, the provider's value evaluation method ProVa (see Section 3.2.6), which was developed in a prior research effort and presented in Paper 3, was utilized.

6.4.1 Applicability of Use Phase-Oriented Value Conception in PSS Design Process

As a result of the study with practitioners in sales and well as services of Levor, a number of value dimensions were identified and subsequently clustered in order to support the quantification of value in the design process¹⁴.

The respondents in the design-focused round of interviews were asked to review the categories shown in Table 5, which were included within clusters formed based on these as presented in Section 7.2.2. During the interviews, the respondents considered and reflected upon the value dimensions against Levor's current offerings: Levor's current PSS offering is availability/use-oriented, while the company is on track to developing and bringing to market full result-oriented PSS. Both offerings can be considered highly integrated PSS as described in Section 2.1.2. Table 6 shows the evaluations of the relevance of the clusters for use during PSS design on a five-point Likert scale, each with respect to product sales, availability/use- or result-oriented PSS. Each evaluation shows the number of times the respective relevance has been selected by the four respondents who completed this part of the interview, while the dimension "Monetary Value" was only evaluated by three respondents.

In addition, the respondents were asked to name further value dimensions which were thought to be of high importance. As this was done before exposing the respondents to the categories identified with practitioners in the use phase, substantial redundancy occurred. However, some additional items exhibiting particular focus on design-critical issues emerged: A project manager for a key component of Levor's result-oriented PSS offerings, for example, remarked on the importance of increased productivity and flexibility, less so with product sales, but particularly with availability/use and result-oriented PSS offerings. Further, a service business developer underlined the aspect of reliability, which he saw particularly critical with PSS offerings. Lastly, an R&D Coordinator particularly underlined the importance of data gathering on the use of the offerings, with a focus on the future use of data mining. This was stated to be a key value to be realized through all aspects of design.

¹⁴ For details on the method used please see Section 3.2.5.

Table 6 – Ranking of clustered value dimensions for relevance in the design process of products, availability/use-oriented or result-oriented PSS.

Clustered Dimension	Business Model	Evaluation					Avg
		Not relevant				Highly relevant	
		1	2	3	4	5	
Long-term thinking	Product sales			4			3
	Availability/Use				4		4
	Result				1	3	4.8
Customer Relations and Service Excellence	Product sales		1	3			2.8
	Availability/Use				3	1	4.3
	Result					4	5
Knowledge and Information	Product sales			4			3
	Availability/Use				3	1	4.2
	Result					4	5
Quality	Product sales			1	1	2	4.3
	Availability/Use				2	2	4.5
	Result				1	3	4.8
Levor Brand and Size	Product sales			3	1		3.3
	Availability/Use				2	2	4.5
	Result					4	5
Monetary Value	Product sales			1	1	1	4
	Availability/Use				1	2	4.7
	Result					3	5

6.4.2 Impact of Value Evaluation on Design Process Adaptation

With the aim of understanding potentials for implementation and use of a provider-centered value concept with support of the ProVa method (see Section 3.2.6), additional inquiries were made to allow for reflection upon the possible use of such an approach, in order to strengthen the focus on a lifecycle-oriented design process when designing Levor's PSS offerings. To support the discussion, the respondents were presented with a simplified assessment table intended to facilitate the use of ProVa. Based on this, the following scenarios for the application of provider's value in PSS design were discussed.

1. Assessment of physical components for inclusion in PSS offerings

Levor continues to have a strong focus on designing physical offerings with a concentration on out-of-the-gate cost. This orientation remains in spite of continuously increasing revenues from its highly integrated PSS offerings. A method-supported evaluation of components and services for their value to the company was seen to be a meaningful approach in order to shift the focus in the design process more towards a lifecycle-oriented point of view. As one of the respondents stated, a continued increase in the revenue stemming from PSS offerings with growing levels of

integration (i.e., result-oriented PSS) is expected, leaving the sales market to focus on affordable, small-scale offerings. In developing incentives for changes in the way PSS are comprised at Levor, a method such as ProVa is seen as a key facilitator.

2. Assessment of projects and new developments

ProVa was further seen as a viable approach towards selecting research projects and development aims to move forward with. When presented with the assessment table, one of the respondents immediately began filling in project ideas and scoring them against the clustered value dimensions. ProVa was considered to be a tool to determine the direction of Levor's development with clear value focus.

3. Learning and understanding

A key aspect of the ProVa method was seen in facilitating and understanding of the provider-focused value concept and its relevance for the design of integrated offerings. The idea of using ProVa in the course of a workshop, rather than in daily business, in order grasp the differences that the business model transition to PSS entails, was reflected positively by the practitioners.

Overall, the applicability and usefulness of ProVa was supported by all the respondents, although it was also stated that a practical trial beyond the scope possible at the occasion of the interview was needed.

7. Discussion

In this section, the results presented above are analyzed and discussed in the context of prior research.

Here, both the implications of the results of the two streams of investigation focused on PSS design methods and process adaptation and the value attained by PSS providers will be discussed, as well as the synergies that can be derived when considering their interaction.

7.1 Companies and Methods – Two Sides of the same Design Adaptation-Coin

In presenting the results of the research performed, challenges with both PSS design methods and the adaptation of internal company processes were put forward. Here, both issues are discussed in a joint subsection, as they reflect upon two sides of the same issue: Companies struggling to adapt processes and adopt methods, and the methods' lack of usability and implementability, further obstructing the achievement of that goal.

7.1.1 The Company View – Challenges in Design Method Adaptation

The existing challenges in the academically-conceived design methods are exacerbated by challenges companies experience in adapting their processes to the new kinds of offerings they provide. Three of the causes of a lacking adaptation of design processes at the case-companies Levor and Navitas were identified. Here, the possible consequences of and counter-measures to this situation are discussed.

In research on implementing PSS in previously product sales-oriented companies, organizational and procedural change and the respective challenges have been discussed in the literature (Manzini, 1999; Windahl, 2007). The research presented here has confirmed and expanded upon the identified challenges. An adaptation in design processes and the use of different methods and approaches is required when designing PSS, in contrast with traditional product-oriented offerings (Sakao, 2011; Vasantha et al., 2012; Wolfenstetter et al., 2015), as otherwise value creation opportunities can be missed, leading to ineffectiveness and thus both economic as well as environmental shortcomings.

Based on the presented results, traditional approaches appear to be particularly unfit to take into account the opportunities provided by the transition of effectiveness goals from the customer to the provider side, as reported in Section 5.2.1. A possible concept to approach this challenge is the understanding of changed internal relationships. As discussed in Lindahl et al. (2014a), highly integrated PSS lead to companies internalizing customer activities, which leads to internal rather than external customers becoming most relevant to deliver input to the design process. In order to identify these internal requirements, internal QFD processes may be a useful approach, which should be preceded by a critical accounting of the relevant parties, e.g. through Actors and System Mapping (Lindahl et al., 2014a). This strategy may

further be fit to alleviate challenges not only with regard to a different structure of incentives and requirements, but also to ensure PSS-relevant stakeholders and their views and requirements are sufficiently included in the design process. As information flows from integrated end-of-first-life divisions are often overlooked (Lindkvist, 2014), a diligent mapping approach can be of significance in efforts towards increasing value attained.

Lastly, the lack of a true lifecycle perspective in both the design and provision of highly integrated PSS is, aside from the issues mentioned in Section 5.2, likely partly caused by the joint development of product sales offerings and PSS: In both Levor and Navitas, product sales have prevailed and are critical to company culture and the employees' self-image. Kowalkowski et al. (2015), in a critical assessment of the so-called "service transition" in PSS providers, conclude that companies offering both PSS and product sales struggle with this duality. These challenges are also exhibited by Levor and Navitas, as there is currently no differentiation in the design processes.

7.1.2 A Focus on Methods – Better Design for Improved Implementability and Usability

In the course of the research on the use of design methods, it was understood that the challenges faced by method development in engineering design and Ecodesign (see e.g. Andreasen, 2011; Lindahl, 2005) are also generally applicable to the design challenges faced by PSS design. Thus, in order help alleviate the challenges shown in Section 5.1 and to support practitioners and academics developing methods for PSS design, a guideline was developed. This guideline contains six characteristics to support implementability and usability of PSS design methods. These characteristics are based on attributes found in a review of existing PSS design methods and feedback given by Navitas' practitioners, which in turn show the presence of industrial adoption promoters counteracting the issues detailed in Section 5.1.3. The characteristics resulting from the research process are shown in Table 7, alongside with an elaboration on the critical elements of the respective items.

A possible operationalization of these characteristics has been discussed. One trajectory is the evaluation of the characteristics shown in Table 7 through a score sheet in order to reduce subjectivity and increase comparability. This approach may include predefined criteria for each characteristic, accompanied by an evaluation scale. Thus far, this operationalization has not been realized, although indications of possible evaluation criteria are given in Paper 2.

Table 7 - Characteristics intended to enhance the implementability and usability of PSS design methods

Characteristic	Key Aspects for PSS Design methods
Modularity	<ul style="list-style-type: none"> • Particularly relevant for stepwise methods • Reduces time required for method use • Increases tolerance for input of low-quality data • Modular approach allows stepwise implementation, which may appear less overwhelming
Simplicity	<ul style="list-style-type: none"> • Reduced functionality: One-trick-pony instead of a Swiss army knife • Clear connection between method process and outcome
Clarity	<ul style="list-style-type: none"> • Academic papers are unfit to communicate to most practitioners • Clear message of content and goal method: Screenshot or similar interactive approach; handbooks; flow diagrams etc.
Customizability	<ul style="list-style-type: none"> • Clear pathways pointing out the adaptability of the method • Split of method tasks over several practitioners to allow for non-workshop utilization
Tangibility	<ul style="list-style-type: none"> • Demonstration of specific outcomes of method use: <ul style="list-style-type: none"> ○ Before and after scenarios ○ Software or spreadsheet-basis
Flexibility	<ul style="list-style-type: none"> • Express usefulness of the method even under uncertainty (as common when implementing PSS) • Mention value-in-use of methods as learning tools in a one-off scenario for practitioners

Nonetheless, even under the absence of a rigid evaluation scheme, method developers should be able to avoid extensive initial testing and error search in order to provide methods of more general applicability and usefulness. This should ensure broader method applicability going beyond only the case company involved in the method's development.

7.2 Understanding the Value in Offering Highly Integrated PSS

Here, the results of the empirical and literature-based investigations into the topic of value for providers of highly integrated PSS are discussed. Beginning from an overall understanding of the meaning and relevance of the value concept for PSS providers, the details of how an actual evaluation can be performed and the relevance of such an endeavor are examined.

7.2.1 General Conceptualization of Provider's Value

Based on the research efforts and results detailed above, a conception of the value that can be attained by providers of highly integrated PSS is explored here.

As described by Kowalkowski et al. (2015), companies often do not fully transition from traditional sales-oriented companies to providers of highly integrated PSS. Rather than moving on a continuum from product to availability provider to performance provider, Kowalkowski et al. (2015) were able to show that many companies often fulfill all of these roles at the same time. This is also true for Levor, which attains the majority of its revenue in developed markets from highly integrated PSS, but nonetheless remains a seller of industrial equipment, although often offering service contracts in conjunction with sales. The duality of these two concepts entails challenges with respect to design and value optimization. Due to historical reasons and PSS still being a relatively new field of business, the challenges resulting from this duality reside mostly with the design and offering of PSS, as the tradition and focus on product sales strengthens this side of the business activity. This has also been reported to be a difficulty in previous studies (Windahl and Lakemond, 2006).

The central motivation for Levor in this research was to understand the differences in the value attained when offering PSS or product sales. The general differences in both approaches, which are applicable to most of the companies discussed in Kowalkowski et al. (2015) are, in a reduced fashion, detailed in Figure 8.

In the case of product sales, the value creation for the provider still relies on Miles' (1971) general formula, as it is determined by function over cost. In such a case, the goods-dominant logic (discussed e.g. in Vargo and Lusch, 2004) applies and value from the provider's point of view is mostly created as value in exchange at the time the sale is made (see upper part of Figure 8). In contrast to this, value for the provider is created throughout the lifetime in the case of highly integrated PSS. From the provider's view, this still constitutes value in exchange – however, in contrast to product sales, the points of exchange become many, spanning the entirety of the lifecycle. In further contrast to product sales, the value attained through highly integrated PSS in many cases spans beyond immediate monetary aspects. In the literature, intangible value (Bertoni et al., 2015; Steiner and Harmon, 2009), for example knowledge, is seen as a key aspect of PSS value creation.

As a result of the overall discussion of research conducted, the general conception of value for providers of highly integrated PSS may be formulated as follows:

The provider’s value in offering highly integrated PSS is captured throughout the lifetime of the offering, in contrast to a focus on monetary value attained at the time of sale. By making use of the benefits of a changed customer-provider relationship and extended provider involvement through a tailored PSS design approach, non-monetary benefits can be attained. These can, under the presumption of a true lifecycle perspective, lead to future advantages in both economic as well as environmental terms.

Figure 8 – Value in product sales vs. value in highly integrated PSS

Disregarding the differences between product sales and highly integrated PSS, Levor still exhibits a strong focus on out-of-the-gate cost with regard to both offerings. This notion is also present in literature focused on the costing of PSS (Settanni et al., 2015). One of the reasons for this is the managerial simplicity of dealing with cost, and thus the value attained for Levor, in such a manner. Therefore, in order to establish a more accurate concept of how value is attained through highly integrated PSS, it must be measurable in some way. The results of the empirical work at Levor are in discussed in the following sections with a focus on this aspect.

7.2.2 Towards Common Value Dimensions for Highly Integrated PSS

Based on the interview study results, it can be said that the issue of a multidimensional value attained by a PSS provider is complex, and one of importance. This assessment is substantiated by high importance being assigned by respondents to nearly all of the identified provider value dimensions. In this context, it should be noted that in most cases, Levor sells service packages together with its sold products, meaning that these offerings can be seen as product-oriented PSS offerings (see Tukker, 2004) rather than a “pure” product sale.

The identified value dimensions are based on the Levor company and, what is more, they are closely tied to the offerings the respondents work with. In order to evaluate the general relevance of the indicators identified, they should be clustered in an effort to find commonalities (see Miles et al., 2013) and to give the possibility to use the evaluation method ProVa without having to perform an analysis of the existing value dimensions within a company. Here, the aggregation was performed based on contextual connections. The broader value dimensions identified are then related to existing research in PSS as detailed in Table 8 and the benefits expected or reported by other researchers. Through this approach, even though the clarity of the identified individual dimensions is somewhat diluted, a stable basis for more general investigations into the providers’ value in PSS is provided, which goes beyond the relevance of the empirical data for Levor alone. A limitation of this approach is that the clustering performed here is non-exclusive, and that other ways of discussing and structuring the attained results are conceivable. The identified clusters are briefly presented in Table 8 in conjunction with examples of supporting literature.

Further value dimensions initially identified in the PSS-focused literature, which have not found an empirical counterpart, are time to market (based on Sakao et al., 2013) and infrastructure (based on Meier et al., 2010).

With the presence of the more general value dimensions shown in Table 8, the basis is laid for an evaluation of components and services with respect to a more appropriate and lifecycle-oriented value concept. The discussion of such an evaluation and approach follows in the next section.

Table 8 – Clustered value dimensions, descriptions and relevant references

Clustered Dimension	Description	Supporting references
Long-Term Thinking	<p>Contains value dimensions: Long-term thinking, security, continuity and environment</p> <ul style="list-style-type: none"> Focus on customer trust, confidence and external stakeholders 	(Baines et al., 2007; Goedkoop et al., 1999; Lindahl et al., 2014b; Mont, 2002b; Sundin et al., 2009; Tukker, 2015, 2004)
Customer Relations and Service Excellence	<p>Contains value dimensions: Effective Service, Simplified Communication, Higher Availability, Quick Response, Customer Relations, Customer Specifications, Customization and Personnel Backup</p> <ul style="list-style-type: none"> Strengthened ties to customers and improving perceived customer value 	(Meier et al., 2010; Sakao et al., 2008)
Knowledge and Information	<p>Contains value dimensions: Increased Competence, Technicians Knowledge, Information and Experience/Knowledge</p> <ul style="list-style-type: none"> Knowledge attained can be key input for design processes Restricting access to knowledge can improve market position 	(Baines et al., 2007; Meier et al., 2010; Sakao et al., 2013)
Quality	<p>Contains value dimensions: Quality and well-designed product</p> <ul style="list-style-type: none"> May be even more relevant than with sales because of extended responsibility 	(Aurich et al., 2006; Kimita et al., 2009a; Morelli, 2006)
Brand and Size	<p>Contains value dimensions: Capacity, Partnership, Packaged Solution and Freedom (Risk Sharing)</p> <ul style="list-style-type: none"> Capability of fulfilling customer requirements at any time and throughout the contract length Key for Levor as the market is dominated by a few, large players → maintaining the capacity to meet customer needs is crucial For small companies: Building capacity and understanding requirements of PSS 	(Neely, 2009)
Monetary Value	<p>Contains value dimensions: Financing, Economy, Cost Forecasting</p> <ul style="list-style-type: none"> Over the long term, all other dimensions must lead to monetary value Win-win-win situation between customer, provider and outside stakeholders are the goal 	(Maussang et al., 2009)

7.2.3 Provider-Centered Value for PSS Design

In a follow-up study, the results discussed in Section 7.2.2 were evaluated for their relevance and usefulness in the assessment of provider-centered value in the process of PSS design. The results underline and reinforce the relevance of the value dimensions identified by practitioners in the use phase of the PSS offering. For all of the value dimensions, the increasing relevance to the value for the provider created throughout the lifetime was particularly confirmed in the case of highly integrated PSS, pointing towards highest relevance for result-oriented PSS. In a similar approach, differences in the value impact on a per-component basis were identified through the initial PVA approach, although the results were less conclusive. This inconclusiveness was likely due to the use phase focus of the practitioners of the first study, while design phase practitioners were able to easily discern differences in relevance and impact for the value dimensions, depending on the business model they were to be used in reference to.

In order to ensure a broader base for the assessment of the value attained by PSS providers, information in that regard was also gathered from respondents involved in the design phase of offering PSS. To ensure that respondents were unbiased by the information collected from use phase practitioners, this data was gathered before exposing the respondents to these findings. In general, there was a large overlap between the value dimensions mentioned in the second round of interviews as compared to the first round, thus confirming the information collected in that phase. There were, however, some additional points mentioned by practitioners such as productivity, flexibility, reliability, data gathering and evaluation. These results indicate that the clustered value dimensions (see Table 8, Section 7.2.2) may not be comprehensive and require extension and flexibility as they are applied in industrial practice, particularly in companies other than Levor.

The areas of application of the identified dimensions for the assessment the provider's value have been found to be broader than initially expected. While the initial focus lay on the evaluation of physical and service components during the design of PSS offerings by way of the ProVa method (see Section 3.2.6 and Paper 3), practitioners also saw opportunities for the use of an evaluation of the provider's value for a development or research project and as a tool for learning and communication. This points to a need for such an assessment, not least in order to accelerate the understanding of PSS as industrial companies increasingly move towards integrated offerings. As part of future research efforts, a short term project has been initiated in order to further investigate the possible usage scenarios and implementation of the ProVa method for evaluation of the provider's value directly in an industrial context.

7.3 Analyzing the Interdependency between Process Adaptation, Value and Methods

Up to this point, the results of the research on PSS design methods and the value in offering PSS have been discussed separately. Now, the interrelations between the two main foci are analyzed and discussed in order to provide a coherent image of the knowledge gained through the research presented.

Considering the research approach (see Section 3.1), the assumption of a strong link between the design approach and the value to be captured by the provider throughout the lifecycle is a reasonable deduction. Based on the results presented with regard to method design, method adoption, design process adaptation and value generation, a link between these different elements has emerged. This, however, is not monocausal, as all of the elements depend on one another. Although this dependency may be more or less strong in some of the cases, and there may be other present aspects that have been missed in this analysis, Figure 9 aims to convey the relevance of the different foci of the investigation to one another.

Figure 9 – Relationship between design methods, design process and value for PSS providers

While adapting existing design processes can lead to an overall enhanced value creation in case highly integrated PSS are offered, a first understanding of this value and how it can contribute to the performance of a PSS provider is needed to justify the actual investments connected to changing existing design processes. In turn, PSS Design methods, which have been designed for usability and implementability, can facilitate and simplify the changes required in the course of a PSS Design process adaptation (see Daalhuizen, 2014). This is because existing and tested methods can reduce the need for trial and error and experimenting by providing pre-defined yet flexible approaches. Vice versa, changed design processes are able to improve upon the procedures of methods themselves, yet again reducing the future room for error in case the lessons learned are being made available to a general audience. The relationship between specific PSS Design methods aimed at facilitating the capturing of provider

value is readily apparent: Where the method provides reliability, repeatability and easier management, the value captured provides the ability to measure actual lifecycle performance, and can thus provide a reflection for which method results had impact and which did not, allowing for further improvements.

The relation between the actual value captured during the lifecycle of the PSS offering and the adaptation or mere existence of a PSS Design approach is analyzed in Figure 9 only on the level of processes, as well as on the overall relationship between the methods, process and value. In addition to this, one may consider the relationship between the elements design process, methods and value creation with respect to the time during the lifecycle in which they are relevant. The value in exchange created for the provider is captured mainly at the intersection of the providers' and customers' spheres (see Grönroos, 2011). With a highly integrated PSS, this refers to the entirety of the use phase of the offering. Similarly to the design paradox (Lindahl, 2005), the extent to which a provider can create and capture value during the use phase of a PSS offering is predetermined, for the most part, during the design.

Figure 10 aims to further support the analysis of the relationship between the use-phase of a PSS offering, where knowledge on matters of the effectiveness in capturing value for the provider can be gathered, and the design phase, where the possibilities of value capture with a future iteration of the offering are determined.

Figure 10 – Freedom of action in design vs. actual value creation and capture during the use-phase

As indicated by Christensen (1992), technological development and product performance typically follow an S-curve. In analogy to this, the knowledge acquired about the value captured by a provider of a PSS offering follows a similar pattern, as shown to the right in Figure 10. In order to gather this usable knowledge on the value creation, the Provider Value Analysis presented in Section 3.2.5 can be utilized. In addition, actual performance data should be gathered with respect to value dimensions in the future, so that the effectiveness of adaptations and changes can be followed up and a true balance to the previous out-of-the-gate cost focus can be achieved. In order to operationalize this knowledge and give it meaning in the design process, the ProVa method for the evaluation and estimation of the attainable value of PSS components, services and activities (as described in Section 3.2.6), as well as projects and research trajectories, may be of utility.

Eventually, through the repeated interaction with knowledge created in different phases of the lifecycle, the attainable benefits of offering highly integrated PSS (see Meier et al., 2010; Tukker, 2015 and further elaborated upon in Section 5.2.2) may be better understood by the relevant practitioners at Levor and other PSS providers. Thereby, a clearer understanding of what the value for a provider in offering PSS actually is and how it can be captured and enhanced, may be created, alongside better knowledge about the PSS offering in a general sense. By making use of the understanding attained by different practitioners and users of a PSS, in manner of a hermeneutical spiraling process¹⁵, the following end may be achieved (see Figure 11): Through repeating the process as shown in Figure 10, an increasingly higher level of understanding can be reached, facilitating both an improvement in economic as well as environmental terms. The level of uncertainty, which is natural when bringing a new type of offering to the market, is ideally constantly reduced, which in turn improves the value created¹⁶ with the next iteration of the offering. There, the spiral starts anew, providing lessons and information on a higher level than previously to the design process.

¹⁵ Hermeneutics are an approach to the understanding of a matter, which occurs, very simply put, through repeatedly revisiting the same issue, applying the new knowledge attained in the meantime (Paterson and Higgs, 2005). This approach has been used here to clarify the expected process of creating a greater understanding for value creation and capture and its basis in the design process of PSS.

¹⁶ As this is quite a universally applicable model of thought, the value for all stakeholders is meant with this. In the narrow sense of this research, this is concentrated on the value as perceived by the PSS provider.

Figure 11 – Interaction between the design and use phase to increase the value created for all stakeholders, illustrated as a hermeneutical spiral (inspired by Paterson and Higgs, 2005).

7.4 Managerial and Environmental Implications

After discussing and analyzing the results of the research, it remains to be seen what the managerial and environmental implications of the findings presented can be. In the following, these findings are very briefly analyzed in order to synthesize key information for practitioners and other interested parties outside the academic domain.

7.4.1 Environmental Implications

As indicated in Section 2.1.3, the expected (Goedkoop et al., 1999; Mont, 2002b) and confirmed (Lelah et al., 2011; Lindahl et al., 2014b) environmental benefits of highly integrated PSS reside largely in efficiency improvements, which in turn can affect resource use. As indicated by the results discussed, the case companies offering highly integrated PSS have adapted their processes insufficiently to this new type of offering and the respective requirements. Both the conceptualization of a lifecycle-oriented value for PSS providers as well as the improved design of methods used to design PSS can be expected to facilitate the adaptation of these processes.

By understanding the changes in incentive structure and the changed way of capturing value through PSS, companies can be encouraged to develop and provide offerings focused on longevity and efficiency – as this is in their best economic interest. Through this, in the form of a win-win scenario, the per-offering¹⁷ resource use can be expected to decrease, along with an extension of the life of the offering and increased efforts with respect to remanufacturing. Thus, the results of this research work, by extending the body of knowledge on PSS and providing information on possible pathways towards increased efficiency and value capture in the design and provision of PSS, can contribute to environmental benefits in the future.

Many of the results presented are discussed with a focus on improved environmental performance. Additional light has been shed on the connection between the provider's value, the approach to designing integrated offerings of products and services, and the connection of these issues to resource efficiency. Nonetheless, there is no automatism between adopting the suggested approaches and improved environmental performance. In current times, where resource scarcity is not yet a decisive factor and the impact of global warming is not yet felt in most western countries, a true vision and dedication is required for companies to not only

¹⁷ It is important to point out that in environmental aspects, this “per-offering” is the unit of measurement. As companies and societies still aspire to more growth, the overall environmental impact will likely not be reduced by the measures described in this research, at least not with respect to the companies Levor and Navitas and their respective sectors. It must be assumed that only a truly circular economy and substantial efforts to temper consumption patterns can lead to an actual reduction of environmental impact on a broad scale.

strive through developing and offering integrated offerings, but to ensure steps are taken towards a more sustainable future.

7.4.2 Managerial Implications

In a condensed fashion, the following implications can be derived based on the research results presented and the synthesis of prior research: In order to reap the benefits of offering highly integrated PSS, the design and development processes should be adapted accordingly. Thus, product-oriented design processes require adjustment. A further important aspect is ensuring and fostering an understanding of the attainable benefits of offering highly integrated PSS within the relevant parts of the company and the respective employees (e.g. Product and Service Design, Sales, Services, Management). As identified in the value-focused research efforts, customer orientation is key the closer the integration with the clients' processes become, but possible benefits for both customer and provider can be overlooked when focusing design only on customer value. A balance of both efforts already in the early design stages is important, and a possible support method for this has been introduced in this research. In addition, understanding the long-term commitment that highly integrated PSS inevitably entail is crucial: A short-term focus in costing and sales likely leads to inefficiencies, erroneous incentive setting, and therefore, lost value-capturing opportunities. Lastly, the use of PSS design methods in the most applicable fashion in the given setting and at the given time can be key: Even learning effects through just a time-efficient, one-time trial can be beneficial to the practitioners' understanding without requiring the overhaul of entire processes.

8. Conclusions and Outlook

This section briefly answers questions that guided the research presented. In addition, possible future research trajectories and questions left unanswered are elaborated on.

8.1 How Companies have adapted their Design Processes to PSS

Research question 1 reads “*How have companies adapted their design processes to offering highly integrated PSS?*” As a result of this research, it has become clear that the design processes within the case companies are hardly adapted to the new types of offerings. In contrast, the research has made evident that a strong product focus remains within these industrial companies in all stages of PSS design.

The causes for this situation can be seen from both a methodological and a company perspective. With a focus on the company-side, the following challenges were found: Firstly, the potential benefits of PSS beyond improved market opportunities appear to have not been understood by all relevant stakeholders within the companies. Secondly, stakeholders with a high level of benefits to attain from good PSS design have insufficient impact on the actual design process. Thirdly, management support for an adaptation of design processes for highly integrated PSS and the respective organizational changes still appears to be lacking.

8.2 Potential Means of Facilitating Improved PSS Design

Research question 2 reads “*What are the potential means of facilitating improved PSS design through the implementation and use of PSS design methods in industrial practice?*” In answering this question, a set of characteristics was developed as a point of departure for an ongoing discussion in PSS research on possible trajectories to improve PSS design methods. The guidelines include six overall characteristics aimed at facilitating industrial adoption of PSS design methods. As a result of applying these characteristics, developers of PSS design methods are able to conceive methods with a better usability and implementability in an industrial context.

In order to further support more comprehensive PSS design with a value focus, companies require a sound understanding of what offering PSS entails. Critical factors identified as a result of the research are that the implications of offering PSS for the stakeholder structure, both internally and externally, as well as the changes in incentives, should be clear. Managers from all relevant divisions (i.e. product and service-development, sales, services, and remanufacturing) should be educated on the most vital issues in connection with PSS in order to enable their support for the changes needed with respect to design improvements, method implementation and process adaptation. In addition, the concept of provider’s value is found to be key to understanding and communicating the true benefit of PSS offerings, and therefore encouraging adaptations within the design process.

8.3 How the Value Attained by Providers throughout the PSS Lifecycle is characterized

Research question 3 is formulated “*How can the value attained by providers throughout the PSS lifecycle be characterized?*” Based on the insight gained in this research, it appears there are notable differences in the value attained by providers of highly integrated PSS in contrast to product sales. These differences materialize in the spread over an extended time frame and are largely characterized by qualitative, hard-to-measure aspects. Further, it has been found that non-monetary aspects can lead to long-term benefits if attended to early in the PSS design process.

A number of value dimensions, suitable for use early in the design of highly integrated PSS, have been identified and verified with a case company. Through the novel approach proposed, practitioners are supported in making lifecycle-focused decisions with a focus on the value captured by the provider when designing highly integrated PSS.

8.4 How the Understanding of the Providers’ Value in Offering PSS can be operationalized

Research question 4 is “*How can the understanding of the providers’ value of offering highly integrated PSS be operationalized for applicability in the PSS Design Process?*” In response to this question, a step-based evaluation method for the evaluation of value for PSS providers of components and services (ProVa) was presented. In the study conducted, ProVa has been found to be an apt tool to convey the novel value concept presented, e.g. in contrast to the current product-oriented focus in the case company. Therefore, ProVa can provide the following benefits if used in the design of highly integrated PSS: A stronger lifecycle focus and therefore better economic utilization of highly integrated PSS’ efficiency potentials, and thus, better environmental performance.

8.5 Concluding Remarks

8.5.1 Method Value Synergies: The Takeaway

In combining the results with a focus on both PSS design methods *and* the matter of value for providers offering PSS, the following conclusions can be drawn:

It is unlikely that efficient value capturing for providers will occur without a rigorous, long-term-focused and well-established PSS design process. PSS design methods are conceived in order to facilitate establishing such a process. It has, however, been discovered that existing methods often fail to meet this end. Regardless, the research conducted has shown that not only methods are at fault: A substantial challenge lies in the problem that the value to be attained by PSS has not been fully understood by companies offering them – as least as far as

parts of these companies are concerned. There, the challenge becomes an issue of communication, of knowledge transfer and of mutual understanding – one that methods for PSS design and previous researchers have already seen.

8.5.2 Generalizability

A key aspect to consider at the conclusion of research that has mainly concentrated on two study objects out of a pool of many is the generalizability of the results. As Flick (2009) puts it: “The generalizability of the results is often closely linked to the way the sampling is done.” With the case companies Levor and Navitas, the sample of companies is relatively small, and with respect to the study foci of PSS design methods and value capture, for the most part, only one company was directly investigated, reducing the basis of the results presented further. Nonetheless, there is good reason to assume a broader generalizability for the results, as long as one considers the nature of the case companies as well as their current stage of implementing PSS design and offering PSS. Both companies, as industrial companies active in different fields of business, can be seen fitting with the PSS providers that have been investigated in earlier studies (e.g. Pezzotta et al., In Press; Tan et al., 2010). Therefore, the results presented and discussed build on existing research and can be used as a basis for future investigations and theory building in the scope of “industrial companies in the process of offering PSS”. Naturally, the results may be far less applicable in small companies or companies without a product-oriented heritage moving into PSS. To broaden the basis of the research and therefore extend the generalizability is a key aspect of the continuing research efforts.

8.5.3 Outlook and Future Research

In the coming research efforts, an even closer integration of the aspects of value and PSS design methods is needed. In this, the lessons with regard to improving usability and implementation of PSS design methods will be applied to the ProVa method, and duly tested in industry application. Further, materials aimed at the wide dissemination and increased availability of ProVa (handbook, video seminar) will be produced. With respect to the providers’ value, the current understanding will be expanded by widening the empirical scope and interviewing a larger number of respondents.

Overall, the future research trajectory aims to expand the empirical base of the findings presented here as well as to apply the identified concepts as broadly as possible, in order to scrutinize their relevance and applicability in many industrial contexts. Ideally, the target is to provide quantitative support that enhances method design, as well as a more comprehensive understanding of the value attained when offering PSS. This can lead to PSS which are economically preferable and enable value creation under the premise of circularity and a substantial reduction in resource use, and thus, significantly improved environmental performance and higher sustainability.

References

- Akao, Y., 2004. Quality Function Deployment: Integrating Customer Requirements Into Product Design. Productivity Press, New York.
- Akasaka, F., Nemoto, Y., Kimita, K., Shimomura, Y., 2012. Development of a knowledge-based design support system for Product-Service Systems. *Comput. Ind.* 63, 309–318.
- Andreasen, M.M., 2011. 45 Years with design methodology. *J. Eng. Des.* 22, 293–332.
- Arai, T., Shimomura, Y., 2004. Proposal of Service CAD System - A Tool for Service Engineering -. *CIRP Ann. - Manuf. Technol.* 53, 397–400.
- Aurich, J.C., Fuchs, C., Wagenknecht, C., 2006. Life cycle oriented design of technical Product-Service Systems. *J. Clean. Prod.* 14, 1480–1494.
- Aurich, J.C., Mannweiler, C., Schweitzer, E., 2010. How to design and offer services successfully. *CIRP J. Manuf. Sci. Technol.* 2, 136–143.
- Baines, T.S., Lightfoot, H.W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M., Wilson, H., 2007. State-of-the-art in product-service systems. *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.* 221, 1543–1552.
- Basu, K., 2013. Shared prosperity and the mitigation of poverty: in practice and in precept, Policy Research Working Paper. The Worldbank.
- Bertoni, A., 2013. Value Driven Design a methodology for value-oriented decision making in preliminary design. Luleå University of Technology.
- Bertoni, A., Bertoni, M., Isaksson, O., 2013. Value visualization in Product Service Systems preliminary design. *J. Clean. Prod.* 53, 103–117.
- Bertoni, A., Bertoni, M., Panarotto, M., Johansson, C., Larsson, T., 2015. Expanding Value Driven Design to Meet Lean Product Service Development. *Procedia CIRP* 30, 197–202.
- Bertoni, M., Eres, H., Isaksson, O., 2011. Criteria for assessing the value of Product Service System design alternatives: an aerospace investigation, in: *Functional Thinking for Value Creation*. Springer Berlin Heidelberg, pp. 141–146.
- Bhagwati, J., Bhagwati, J.N., Panagariya, A., 2013. *Why Growth Matters: How Economic Growth in India Reduced Poverty and the Lessons for Other Developing Countries*. PublicAffairs, New York.
- Birch, A., Hon, K.K.B., Short, T., 2012. Structure and output mechanisms in Design for Environment (DfE) tools. *J. Clean. Prod.* 35, 50–58.

- Blessing, L.T.M., Chakrabarti, A., 2009. *DRM, a Design Research Methodology*. Springer London, London.
- Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. *J. Clean. Prod.* 65, 42–56.
- Boehm, M., Thomas, O., 2013. 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.* 51, 245–260.
- Brezet, H., Hemel, C. Van, Böttcher, H., 1997. Ecodesign: a promising approach to sustainable production and consumption. *UNEP Industry and Environment*.
- Ceci, F., Prencipe, A., 2008. Configuring Capabilities for Integrated Solutions: Evidence from the IT Sector. *Ind. Innov.* 15, 277–296.
- Christensen, C.M., 1992. Exploring the Limits of the Technology S-Curve, Part I: Component Technologies. *Prod. Oper. Manag.* 1, 334–357.
- Collopy, P.D., Hollingsworth, P.M., 2012. Value-Driven Design. *J. Aircr.* 48, 749–759.
- Daalhuizen, J.J., 2014. *Method Usage in Design: How methods function as mental tools for designers*. Delft University of Technology.
- Dankbaar, B., 1997. Lean Production: Denial, Confirmation or Extension of Sociotechnical Systems Design? *Hum. Relations* 50, 567–583.
- Deaton, A., 2010. Price indexes, inequality, and the measurement of world poverty. *Am. Econ. Rev.* 100, 3–34.
- Denzin, N.K., 1989. *The Research Act*. Prentice Hall, Englewood Cliffs.
- Desai, A., Lindahl, M., Widgren, M., In Press. Actors and System Maps – A Methodology for Developing Product/Service Systems, in: Matsumoto, M., Masui, K., Fukushige, S., Kondo, S. (Eds.), *Sustainability through Innovation in Product Life Cycle Design*. Springer Singapore.
- Diehl, J.C., Christiaans, H., 2015. Product Service Systems: The future for Designers? The changing role of the industrial designer, in: *Proceedings International Design Congress*.
- Dumay, J., 2014. 15 years of the Journal of Intellectual Capital and counting. *J. Intellect. Cap.* 15, 2–37.
- Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., Stechow, C. von, Zwickel, T., Minx, J., 2014. *Climate Change 2014: Mitigation of*

Climate Change. Cambridge, UK and New York, USA.

Eggert, A., Ulaga, W., Schultz, F., 2006. Value creation in the relationship life cycle: A quasi-longitudinal analysis. *Ind. Mark. Manag.* 35, 20–27.

European Commission, 2013. COMMISSION REGULATION (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for vacuum cleaners. *Off. J. Eur. Union* 24–34.

Fernandes, M., 2012. A Holistic and Cultural view of Value. *Adv. Manag. Appl. Econ.* 2, 55–107.

Flick, U., 2009. *An Introduction to Qualitative Research*. SAGE Publications, London, UK.

Geis, C., Bierhals, R., Schuster, I., Badke-Schaub, P., Birkhofer, H., 2008. Methods in Practice – A study on requirements for development and transfer of design methods, in: *Design 2008 - 10th International Design Conference*.

Goedkoop, M.J., Van Halen, C.J.G., Te Riele, H.R.M., Rommens, P.J.M., 1999. Product Service systems, Ecological and Economic Basics. *Econ. Aff.* 36, 132.

Goldstein, L. 1967-, 1994. The strategic management of environmental issues : a case study of Kodak's single-use cameras.

Gottberg, A., Morris, J., Pollard, S., Mark-Herbert, C., Cook, M., 2006. Producer responsibility, waste minimisation and the WEEE Directive: Case studies in eco-design from the European lighting sector. *Sci. Total Environ.* 359, 38–56.

Grönroos, C., 2011. Value co-creation in service logic: A critical analysis. *Mark. Theory* 11, 279–301.

Grönroos, C., 2008. Service logic revisited: who creates value? And who co-creates? *Eur. Bus. Rev.* 20, 298–314.

Grönroos, C., Ravald, A., 2011. Service as business logic: implications for value creation and marketing. *J. Serv. Manag.* 22, 5–22.

Grönroos, C., Voima, P., 2013. Critical service logic: making sense of value creation and co-creation. *J. Acad. Mark. Sci.* 41, 133–150.

Hartzell, C.A., Hoddie, M., Bauer, M., 2010. Economic Liberalization via IMF Structural Adjustment: Sowing the Seeds of Civil War? *Int. Organ.* 64, 339.

Hertwich, E.G., 2008. Consumption and the Rebound Effect: An Industrial Ecology Perspective. *J. Ind. Ecol.* 9, 85–98.

Hänsch Beuren, F., Gomes Ferreira, M.G., Cauchick Miguel, P.A., 2013. Product-service

- systems: a literature review on integrated products and services. *J. Clean. Prod.* 47, 222–231.
- Isaksson, O., Bertoni, M., Hallstedt, S., Lavesson, N., 2015. Model Based Decision Support for Value and Sustainability in Product Development. 20th Int. Conf. Eng. Des. (ICED), Milan.
- Jänsch, J., Birkhofer, H., 2007. Imparting Design Methods With the Strategies of Experts, in: ICED07: 16th International Conference of Engineering Design.
- Kimita, K., Shimomura, Y., Arai, T., 2009a. Evaluation of customer satisfaction for PSS design. *J. Manuf. Technol. Manag.* 20, 654–673.
- Kimita, K., Shimomura, Y., Arai, T., 2009b. A customer value model for sustainable service design. *CIRP J. Manuf. Sci. Technol.* 1, 254–261.
- Knight, P., Jenkins, J.O., 2009. Adopting and applying eco-design techniques: a practitioners perspective. *J. Clean. Prod.* 17, 549–558.
- Kowalkowski, C., Kindström, D., 2009. Value visualization strategies for PSS development, in: Sakao, T., Lindahl, M. (Eds.), *Introduction to Product/Service-System Design*. Springer-Verlag London, pp. 159–181.
- Kowalkowski, C., Windahl, C., Kindström, D., Gebauer, H., 2015. What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies. *Ind. Mark. Manag.* 45, 59–69.
- Le Pochat, S., Bertoluci, G., Froelich, D., 2007. Integrating ecodesign by conducting changes in SMEs. *J. Clean. Prod.* 15, 671–680.
- Lelah, A., Mathieux, F., Brissaud, D., 2011. Contributions to eco-design of machine-to-machine product service systems: the example of waste glass collection. *J. Clean. Prod.* 19, 1033–1044.
- Lillis, A.M., 1999. A framework for the analysis of interview data from multiple field research sites. *Account. Financ.* 39, 79–105.
- Lim, C.-H., Kim, K.-J., Hong, Y.-S., Park, K., 2012. PSS Board: a structured tool for product-service system process visualization. *J. Clean. Prod.* 37, 42–53.
- Lindahl, M., 2005. Engineering Designers' Requirements on Design for Environment Methods and Tools. KTH.
- Lindahl, M., Sakao, T., Carlsson, E., 2014a. Actors and System Maps for Integrated Product Service Offerings – Practical Experience from Two Companies. *Procedia CIRP* 16, 320–325.

- Lindahl, M., Sundin, E., Rönnbäck, A., Ölundh, G., Östlin, J., 2006. Integrated product and service engineering—the IPSE project, in: *Perspectives on Radical Changes to Sustainable Consumption and Production (SCP)*. Copenhagen, pp. 315–324.
- Lindahl, M., Sundin, E., Sakao, T., 2014b. Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. *J. Clean. Prod.* 64, 288–296.
- Lindkvist, L., 2014. *Exploring Product Life-Cycle Information Flows with a Focus on Remanufacturing*. Linköping University Electronic Press.
- Lofthouse, V., 2006. Ecodesign tools for designers: defining the requirements. *J. Clean. Prod.* 14, 1386–1395.
- Lopez-Mesa, B., 2006. Design Methods and their sound use in Practice, in: *Design Methods for Practice*. pp. 87–94.
- López-Mesa, B., Thompson, G., 2006. On the significance of cognitive style and the selection of appropriate design methods. *J. Eng. Des.* 17, 371–386.
- Manzini, E., 1999. Strategic design for sustainability: towards a new mix of products and services, in: *Proceedings First International Symposium on Environmentally Conscious Design and Inverse Manufacturing*. IEEE, pp. 434–437.
- Manzini, E., Vezzoli, C., 2003. A strategic design approach to develop sustainable product service systems: examples taken from the “environmentally friendly innovation” Italian prize. *J. Clean. Prod.* 11, 851–857.
- Manzini, E., Vezzoli, C., Clark, G., 2001. Product-Service Systems: Using an Existing Concept as a New Approach to Sustainability. *J. Des. Res.* 1.
- Martinez, V., Bastl, M., Kingston, J., Evans, S., 2010. Challenges in transforming manufacturing organisations into product-service providers. *J. Manuf. Technol. Manag.* 21, 449–469.
- Matschewsky, J., In Press. PSS without PSS Design - Possible Causes, Effects and Solutions, in: Matsumoto, M., Masui, K., Fukushige, S., Kondoh, S. (Eds.), *Sustainability through Innovation in Product Life Cycle Design*. Springer Singapore.
- Matschewsky, J., 2012. Evaluation and optimization of Product/Service Systems within the development process. Hochschule für Technik und Wirtschaft Dresden.
- Matschewsky, J., Lindahl, M., Sakao, T., 2015a. Facilitating Industrial Adoption of Design Methods for Product-Service Systems, in: *ICED15: 20th International Conference on Engineering Design*. Milan, pp. 301–310.
- Matschewsky, J., Sakao, T., Lindahl, M., 2015b. ProVa – Provider Value Evaluation for

Integrated Product Service Offerings. *Procedia CIRP* 30, 305–310.

Maussang, N., Zwolinski, P., Brissaud, D., 2009. Product-service system design methodology: from the PSS architecture design to the products specifications. *J. Eng. Des.* 20, 349–366.

Meier, H., Roy, R., Seliger, G., 2010. Industrial Product-Service Systems-IPS2. *CIRP Ann. - Manuf. Technol.* 59, 607–627.

Meuser, M., Nagel, U., 2002. ExpertInneninterviews—vielfach erprobt, wenig bedacht, in: Bogner, A., Littig, B., Menz, W. (Eds.), *Das Experteninterview*. Verlag für Sozialwissenschaften, pp. 71–93.

Miles, L.D., 1971. *Techniques of value analysis and engineering*. McGraw-Hill.

Miles, M., Huberman, A., Saldaña, J., 2013. *Qualitative data analysis: A methods sourcebook*. SAGE Publications.

Miller, M., Mattes, K., 2014. Demonstration of a multi-criteria based decision support framework for selecting PSS to increase resource efficiency (No. S11/2014), Working Paper Sustainability and Innovation.

Mont, O., 2002a. Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. *J. Sustain. Prod. Des.* 2, 89–103.

Mont, O., 2002b. Clarifying the concept of product–service system. *J. Clean. Prod.* 10, 237–245.

Morelli, N., 2006. Developing new product service systems (PSS): methodologies and operational tools. *J. Clean. Prod.* 14, 1495–1501.

Müller, P., Kebir, N., Stark, R., Blessing, L., 2009. PSS layer method - application to microenergy systems, in: Sakao, T., Lindahl, M. (Eds.), *Introduction to Product/Service-System Design*. Springer London, pp. 3–30.

Neely, A., 2009. Exploring the financial consequences of the servitization of manufacturing. *Oper. Manag. Res.* 1, 103–118.

O'Hare, J.A., 2010. *Eco-Innovation Tools for the Early Stages: An Industry-Based Investigation of Tool Customisation and Introduction*. University of Bath.

OECD, 2016. *Country statistical profile: Sweden*. Ctry. Stat. profiles Key tables from OECD.

Ostry, J.D., Berg, A., 2011. Inequality and Unsustainable Growth; Two Sides of the Same Coin? IMF Staff Discuss. Notes.

Panarotto, M., 2015. *A Model-Based Methodology for Value Assessment in Conceptual*

Design. Blekinge Tekniska Högskola.

- Paterson, M., Higgs, J., 2005. Using Hermeneutics as a Qualitative Research Approach in Professional Practice. *Qual. Rep.* 10, 339–357.
- Patton, M.Q., 2002. *Qualitative Research & Evaluation Methods*. SAGE Publications.
- Payne, A.F., Storbacka, K., Frow, P., 2007. Managing the co-creation of value. *J. Acad. Mark. Sci.* 36, 83–96.
- Pezzotta, G., Pinto, R., Pirola, F., Ouertani, M.-Z., 2014. Balancing Product-service Provider's Performance and Customer's Value: The SService Engineering Methodology (SEEM). *Procedia CIRP* 16, 50–55.
- Pezzotta, G., Pirola, F., Rondini, A., Pinto, R., Ouertani, M.-Z., In Press. Towards a methodology to engineer industrial product-service system – Evidence from power and automation industry. *CIRP J. Manuf. Sci. Technol.*
- Pigosso, D.C.A., Rozenfeld, H., McAloone, T.C., 2013. Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. *J. Clean. Prod.* 59, 160–173.
- Plouffe, S., Lanoie, P., Berneman, C., Vernier, M.-F., 2011. Economic benefits tied to ecodesign. *J. Clean. Prod.* 19, 573–579.
- Qu, M., Yu, S., Chen, D., Chu, J., Tian, B., 2016. State-of-the-art of design, evaluation, and operation methodologies in product service systems. *Comput. Ind.* 77, 1–14.
- Reim, W., Parida, V., Örtqvist, D., 2015. Product–Service Systems (PSS) business models and tactics – a systematic literature review. *J. Clean. Prod.* 97, 61–75.
- Rosenbaum, W.A., 2013. *Environmental Politics and Policy*. SAGE Publications.
- Sakao, T., 2011. What is PSS design? – Explained with two industrial cases. *Procedia - Soc. Behav. Sci.* 25, 403–407.
- Sakao, T., Birkhofer, H., Panshef, V., Dörsam, E., 2009. An effective and efficient method to design services: empirical study for services by an investment-machine manufacturer. *Int. J. Internet Manuf. Serv.* 2, 95–110.
- Sakao, T., Lindahl, M., 2015. A method to improve integrated product service offerings based on life cycle costing. *CIRP Ann. - Manuf. Technol.* 64, 33–36.
- Sakao, T., Lindahl, M., 2012. A value based evaluation method for Product/Service System using design information. *CIRP Ann. - Manuf. Technol.* 61, 51–54.
- Sakao, T., Mizuyama, H., 2014. Understanding of a product/service system design: a holistic approach to support design for remanufacturing. *J. Remanufacturing* 4, 1–24.

- Sakao, T., Napolitano, N., Tronci, M., Sundin, E., Lindahl, M., 2008. How are product-service combined offers provided in Germany and Italy? Analysis with company sizes and countries. *J. Syst. Sci. Syst. Eng.* 17, 367–381.
- Sakao, T., Shimomura, Y., 2007. Service Engineering: a novel engineering discipline for producers to increase value combining service and product. *J. Clean. Prod.* 15, 590–604.
- Sakao, T., Öhrwall Rönnbäck, A., Ölundh Sandström, G., 2013. Uncovering benefits and risks of integrated product service offerings - Using a case of technology encapsulation. *J. Syst. Sci. Syst. Eng.* 22, 421–439.
- Schneider, F., Kallis, G., Martinez-Alier, J., 2010. Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. *J. Clean. Prod.* 18, 511–518.
- Schön, D., 1983. *The reflective practitioner: How professionals think in action.* Basic Books.
- Settanni, E., Thenent, N.E., Newnes, L.B., Parry, G., Goh, Y.M., 2015. To Cost an Elephant: An Exploratory Survey on Cost Estimating Practice in the Light of Product-Service-Systems. *J. Cost Anal. Parametr.* 8, 1–22.
- Shimomura, Y., Hara, T., Arai, T., 2009. A unified representation scheme for effective PSS development. *CIRP Ann. - Manuf. Technol.* 58, 379–382.
- Simon, H.A., 1969. *The Sciences of the Artificial.* MIT Press, Cambridge, Mass.
- Steiner, F., Harmon, R., 2009. The impact of intangible value on the design and marketing of new products and services: An exploratory approach, in: *PICMET '09 - 2009 Portland International Conference on Management of Engineering & Technology.* IEEE, pp. 2066–2079.
- Stern, N., 2007. *The Stern Review: The Economics of Climate Change.* London.
- Sullivan, P.H., McLean, R., 2007. The confusing task of measuring intangible value. *Intellect. Asset Manag.* 23, 36–41.
- Sundin, E., Lindahl, M., Ijomah, W., 2009. Product design for product/service systems. *J. Manuf. Technol. Manag.* 20, 723–753.
- Sundin, E., Östlin, J., Öhrwall Rönnbäck, A., Lindahl, M., Sandström, G., 2008. Remanufacturing of Products used in Product Service System Offerings, in: *Mitsubishi, M., Ueda, K., Kimura, F. (Eds.), Manufacturing Systems and Technologies for the New Frontier SE - 110.* Springer London, pp. 537–542.
- Tan, A.R., Matzen, D., McAloone, T.C., Evans, S., 2010. Strategies for designing and developing services for manufacturing firms. *CIRP J. Manuf. Sci. Technol.* 3, 90–97.

- Tukker, A., 2015. Product services for a resource-efficient and circular economy – a review. *J. Clean. Prod.* 97, 76–91.
- Tukker, A., 2004. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Bus. Strateg. Environ.* 13, 246–260.
- Tukker, A., Tischner, U., 2006. Product-services as a research field: past, present and future. Reflections from a decade of research. *J. Clean. Prod.* 14, 1552–1556.
- Vallejo-Allonso, B., Rodríguez-Castellanos, A., Arregui-Ayastuy, G., 2010. Identifying, Measuring, and Valuing Knowledge-Based Intangible Assets: New Perspectives. IGI Global.
- van den Bergh, J.C.J.M., 2011. Environment versus growth — A criticism of “degrowth” and a plea for “a-growth.” *Ecol. Econ.* 70, 881–890.
- van Halen, C., Vezzoli, C., Wimmer, R., 2005. Methodology for Product Service System Innovation: How to Develop Clean, Clever and Competitive Strategies in Companies. Uitgeverij Van Gorcum.
- Vargo, S.L., Lusch, R.F., 2004. Evolving to a New Dominant Logic for Marketing. *J. Mark.* 68, 1–17.
- Vargo, S.L., Maglio, P.P., Akaka, M.A., 2008. On value and value co-creation: A service systems and service logic perspective. *Eur. Manag. J.* 26, 145–152.
- Vasantha, G.V.A., Roy, R., Corney, J.R., 2015. Advances in Designing Product-Service Systems. *J. Indian Inst. Sci.* 95, 429–447.
- Vasantha, G.V.A., Roy, R., Lelah, A., Brissaud, D., 2012. A review of product-service systems design methodologies. *J. Eng. Des.* 23, 635–659.
- Vezzoli, C., Ceschin, F., Diehl, J.C., Kohtala, C., 2015. New Design Challenges to Widely Implement “Sustainable Product-Service Systems.” *J. Clean. Prod.* 97, 1–12.
- Vezzoli, C., Kohtala, C., Srinivasan, A., Xin, L., Fusakul, M., Sateesh, D., Diehl, J.C., 2014. Product-Service System Design for Sustainability. Greenleaf Publishing, Sheffield, UK.
- Windahl, C., 2007. Integrated Solutions in the Capital Goods Sector : Exploring innovation, service and network perspectives. Linköping University Electronic Press.
- Windahl, C., Lakemond, N., 2006. Developing integrated solutions: The importance of relationships within the network. *Ind. Mark. Manag.* 35, 806–818.
- Wolfenstetter, T., Bohm, M., Krcmar, H., Brundl, S., 2015. Why product service systems development is special, in: 2015 International Conference on Industrial Engineering and Systems Management (IESM). IEEE, pp. 1221–1228.

World Bank Group, 2016. Global Monitoring Report 2015/2016: Development Goals in an Era of Demographic Change. Washington DC.

Yin, R.K., 2013. Case Study Research: Design and Methods. SAGE Publications.

Zangemeister, C., 1976. Nutzwertanalyse in der Systemtechnik: Eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen. Wittmannsche Buchhandlung, München.

We are not going to be able to operate our Spaceship Earth successfully
nor for much longer, unless we see it as a whole Spaceship,
and our fate as common.

It has to be everybody or nobody.

R. Buckminster Fuller