PSS Without PSS Design: Possible Causes, Effects, and Solutions

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Abstract Product-service systems (PSS) are seen as a cornerstone of a future circular economy. However, in order to achieve the desired environmental benefits, the industrial implementation of PSS design is key. This chapter discusses the apparent lack of an adaptation of design processes to PSS or adoption of PSS design methods within companies, which are nevertheless successfully offering PSS. Based on experiences at two companies and under close regard of the relevant literature, possible causes of this lack of method adaptation/adoption are discussed, and the effects this may have are deliberated. Lastly, potential solutions to this issue and ways forward are introduced and reflected upon focusing on the companies.

Keywords Method adoption • Process adaptation • Business model • Integrated product service engineering • EcoDesign

1 Introduction

1.1 Background, Motivation, and Goals

Resource scarcity is becoming an increasing pressure, as, although faced with a finite planet, resource use on earth currently only knows one direction – up [1]. Confronted with this challenge, particularly the industries of developed countries have identified one critical component in coping with this: doing more with less, i.e., decoupling resource use and value creation, in one word, dematerialization. This has been a cornerstone of product-service systems (PSS) since an intensive phase of research on PSS commenced in the late 1990s [2, 3]. Through the efficiency aspects associated with them, PSS are hoped to become a key component of a still utopian circular economy [4].

However, the benefits of PSS as a business innovation, which can provide tremendous opportunities, do come at a cost: The implementation of good PSS

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design. Good PSS design takes the entire life cycle into account and provides a high level of integration of products and services, beginning at the earliest stages of design (see, e.g., [5–7]).

During on-site research activities with two industrial PSS providers, a broad understanding was created for the design processes and procedures employed at the companies. Due to reasons of anonymity, these companies shall be called "Levor" and "Navitas" within this chapter. Both are providers of industrial goods and PSS and are among the world leaders in their respective domain.

Under the course of the research, it became increasingly clear that the design processes applied were either not or only slightly adapted to the altered requirements brought about by the introduction of PSS. This is surprising, as both companies are successful in offering PSS, with one of them having a higher number of PSS sold than traditional product sales offerings in certain markets. The question arose, whether or not the academic presumption that design processes must be adjusted to PSS is simply wrong – or whether the lacking adoption has other causes. In the course of the research, it was found that the latter is the case. Consequently, implications of this as well as possible ways of remedying the situation were then taken into focus. An additional research motivation was the lack of literature on this matter in the area of PSS design.

Based on the knowledge gathered, this chapter aims 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.

1.2 Research Approach

The information collected at "Levor" and "Navitas" was evaluated with close focus on state-of-the-art literature in the field. Three areas were identified as possible causes for the described phenomenon. Probable (future) implications of the lacking adaptation of design processes to PSS are discussed with respect to business as well as the environmental considerations. Potential solutions to this issue are discussed within the same boundaries, and their implications at the case companies are briefly reported. Even though the presented threefold of possible causes, effects, and solutions can neither be considered universally applicable nor comprehensive, the strong integration of literature employed in the reasoning ensures that the new knowledge which is presented is relevant to both academics and practitioners alike. For academics, this chapter may be considered an impulse to examine own industrial experiences in order to contribute to its extension. For practitioners it may serve as a further clarification of PSS benefits, an incentive to more quickly move to a full integration of PSS and to embrace both challenges and opportunities PSS can provide.

1.3 Structure

The chapter commences by explaining the methodological approach of the research in Sect. 2. Subsequently in Sect. 3, the need for PSS design as such is discussed. Hereafter, in Sect. 4, possible causes for a lack of adaptation of design processes to PSS are evaluated. In Sect. 5, business- as well as environment-related effects and possible solutions are discussed. Sect. 6 then concludes the chapter, summarizing its content and giving an outlook on forthcoming research efforts on this topic.

2 Methodology

2.1 Literature Review

In order to relate the empirical findings and suggestions for process improvement to the state of the art in PSS design research, a thorough literature study was performed. A part of the literature used was gathered for a recent literature-focused paper on implementability of PSS design methods [8]. Further literature was collected through keyword searches, predominantly in the Scopus engine. Keywords or strings used included but were not limited to *PSS design benefits*, *PSS design efficiency*, *PSS design methodology*, *organizational challenges and PSS*, and *managerial support and PSS*. Due to space restrictions, only the most relevant publications were used.

2.2 Actor Maps

In an effort to fully understand the connections between the actors involved in designing a PSS offering as well as the information exchanged between them, interviews to derive "Actor Maps" were conducted with designers and project managers at "Levor." A full account of the "Actors and System Maps" method can be found in [9]. Each of the participants of the interviews was informed in advance through a one-sheet about the method that would be used during the interview. They were further informed that the focus would be on their immediate working tasks, the information they exchanged while fulfilling these tasks, and the methods used for fulfilling them. During the interview, the information given by the participant was mapped on a whiteboard and subsequently digitalized using Microsoft Visio.

This chapter utilizes the information and understanding gathered as a point of departure for a deeper examination of the possible causes of the identified low adaptation of design processes to the integrated offerings provided by "Levor."

2.3 Understanding Product/Service Integration: The "Navitas" Case Study

A PSS design methodology was tested and evaluated at "Navitas" for several years. During this process, a profound understanding for the inner workings of the company with respect to product and service design was derived, after many meetings and interviews with a substantial number of employees active in design of products, services, as well as management. In light of the data and knowledge gathered during this time, the results reported here were obtained in order to investigate the perceived contradiction between offering PSS and the challenge to adapt processes to the new business model. Further, an effort is made to present a convergent result (cf. [10]).

3 Why PSS Design?

Before discussing the issue of a lack of PSS design in companies offering PSS, first the need for new design approaches to be implemented by practitioners must be clarified. A significant portion of the research on PSS has been dedicated to the topic of PSS design (see, e.g., [5]). Implementing integrated offerings in a company previously active in the sale of products is a tremendous challenge, and researchers involved with PSS appear to largely take the relevance and necessity of a particular approach toward the design of these offerings as a given. Nonetheless, a few significant points made in literature are discussed in the following in order to support the reasoning in the coming sections of this chapter.

The design divisions of companies are faced with a substantial complexity due to the need to integrate products and services if a PSS implementation is to be successful. A PSS design framework helps cope with this, while traditional engineering methods are also considered useful if enhanced to fit the new challenges [11]. Particularly the possibility of clarifying the relationship between service and the value created as a benefit of PSS design is seen as an advantage [6]. This is extended further in [12] by stating that in addition to the traditional, product-focused paradigm of functional requirements, PSS design serves to fulfill customer value. This goes beyond functional requirements, and, therefore, an approach must be taken that goes beyond traditional product design. When clarifying the concept of PSS design, [13] describes PSS design as "design toward stakeholders [which] provides designers with new degrees of freedom and covers an earlier phase of design." This difference is particularly apparent when considering the sustainability aspects of PSS [13]. A further particularity that PSS design aims to tackle is the iterative nature of the development [4], going so far as to describe the process of PSS design as based on "trial and error." This can be attributed to the quite early stage that PSS are in with respect to their industrial deployment, and it all the more clarifies the need for fitting methods to be used. A lack of adaptation of the physical

design when transitioning toward PSS is a further issue in case the broad and life cycle-oriented perspective of PSS design is omitted [14]. On a similar note, integrated design of products and services is seen as a cornerstone of providing environmentally beneficial PSS, particularly with respect to result-oriented PSS offerings [15]. Special focus is also put on balancing the issue of customer value with internal company capability [16], which traditional product design paradigms do not offer. Lastly, a lack of focus on service during the design process may serve to increase operational cost [17].

Overall, a number of benefits of and needs for implementing PSS design have been identified. Nonetheless, the implementation of PSS design methods in industrial practice is lacking [18]. After discussing the adaptation of PSS design methods and tools to support their implementation in the industry [8], this chapter aims to shed a light on the company side of this challenge in the coming sections.

4 Why Companies Are Not Utilizing PSS Design

In this section, three overall issues are discussed that may lead companies that offer PSS to not implement PSS design methods or adapt their design processes to the changing needs in light of this new offering. The understanding for the processes within two industrial companies offering PSS, which was created during two industry-focused research projects, serves as the basis for deriving the causes for companies not to implement PSS. Literature is used to interpret and support the findings and observations made.

4.1 Reduced Customer Pressure

PSS dilute the boundaries between customer and provider, particularly in the case of highly integrated (availability- or result-oriented) business models [6]. The traditional border between customer and provider, which also marked the border between one actor establishing requirements and the other actor fulfilling these requirements, is increasingly disappearing. An illustration of the product sales-oriented relationship is given in Fig. 1, visualized by the dark green color.

In product sales, customers have strong incentives to set requirements concentrated on both matters of efficiency (achieving the desired goal with minimal resource use) and effectiveness (achieving the desired goal in the required quality). The provider aims balance both factors in order to deliver value to the customer (see Fig. 1). In the case of "Levor," the company has been traditionally excellent in taking account of customer requirements through principles of lean [19]. The path of handling customer requirements as perceived by an engineering designer is illustrated in Fig. 2 (blue solid path). This process is similar to processes utilized by many product-oriented industrial companies (see, e.g., requirement specification

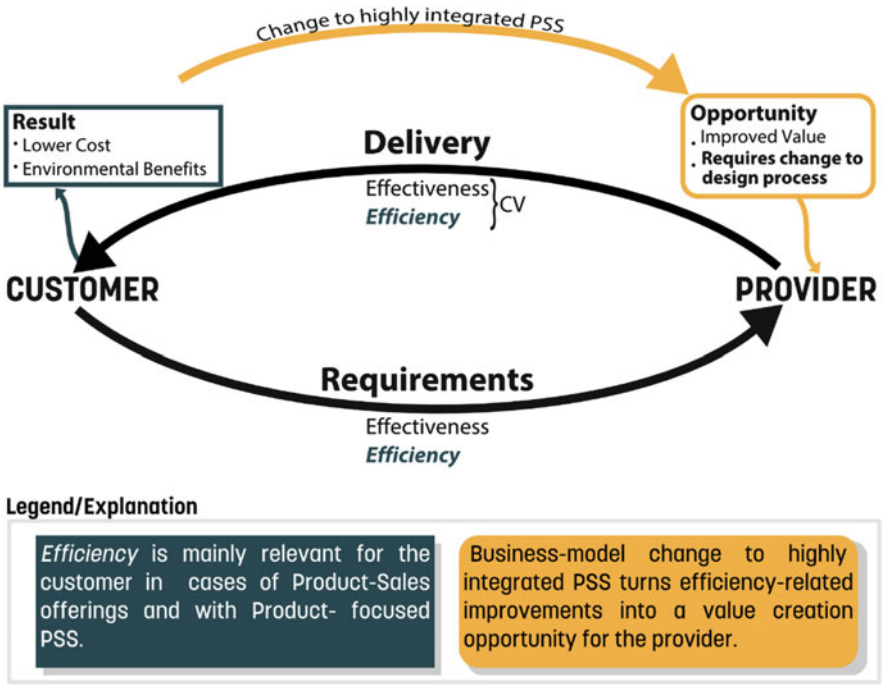

Fig. 1 New value creation opportunities for providers when transitioning to integrated PSS business models

in [20], pg. 146). Today, "Levor" offers, besides their traditional product sales tier, a model which can be described as a highly integrated PSS [6]. Through this, as further shown in Fig. 1, efficiency improvements are no longer prioritized by companies offering highly integrated PSS, especially with regard to customer-oriented processes. This is particularly notable, as many of the efficiency-related requirements have a direct impact on environmental performance and sustainability, an area on which many PSS design methods lay particular focus (see, e.g., [21]). Without the pressure of fulfilling increasingly demanding customer requirements, companies have a much lower incentive to adapt their processes to PSS design and to implement PSS design methods. A reduced use of the established process of addressing customer requirements and the lack of a new process to handle the internalized efficiency requirements may lead to a lower perceived need for process adaptation and, thus, the adoption of PSS design methods and tools. The high technological aptitude of "Levor" to fulfill the set requirements on effectiveness could further strengthen the impression that no change to current processes is needed. This may be even further enhanced by the fact that offerings for traditional sales and PSS are jointly developed at "Levor."

In summary, it can be stated that a lacking awareness of new value creation opportunities (cf. yellow parts of Fig. 1) and therefore an impeded adaptation of the

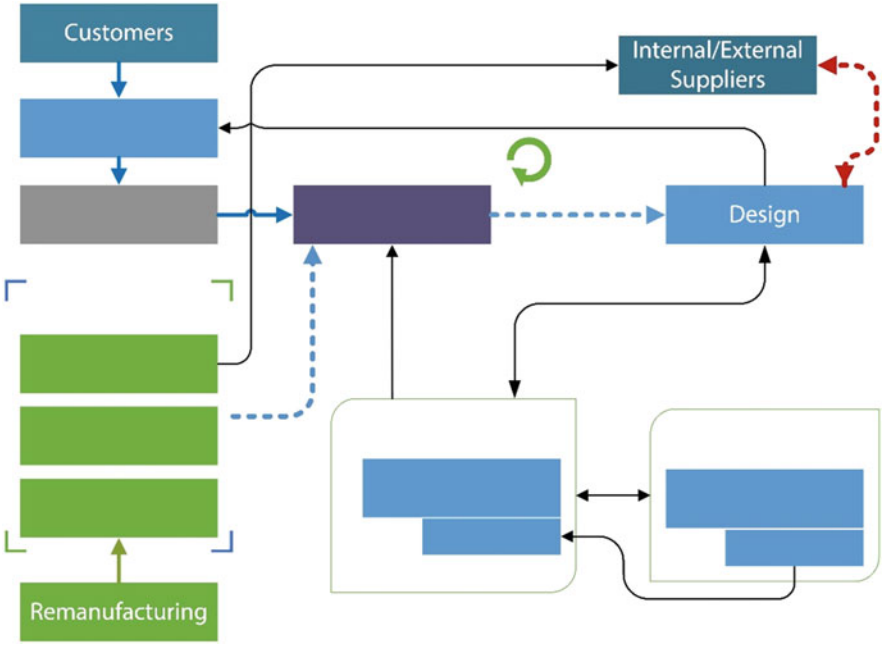

Fig. 2 Information between manufacturing and design during conceptual (*blue dotted*) and detailed design (*red dotted*), informal feedback stream from remanufacturing (*green solid*), and customer input (*blue solid*). Blurred due to confidentiality requirements

handling of internal requirements may play a role in an underdeveloped adaptation of design processes to PSS offerings.

4.2 Lack of Involvement of Internal Stakeholders Who Are Key to PSS Design

A significant portion of the impact of lean engineering on the manufacturing industry stems from the concept of cooperation during the design and development process, particularly between manufacturing and design [22]. This close relationship is reflected in the process employed at "Levor" as seen by a design engineer, signified by the blue and red dotted lines in Fig. 2. Again, this process is likely to be similar in other companies due to the lean design approach [19]. Because of that, the identified items bear general relevance beyond this case company.

PSS design has a strong impact on many actors and stakeholders throughout the life cycle of an offering. However, service/maintenance and remanufacturing are among the activities most strongly affected by this business model change [14]. Due to this, service/maintenance and remanufacturing are sensitive to well-executed PSS design, i.e., they benefit from positive developments, and lacking

progress becomes noticeable to them earlier and more profoundly than to other stakeholders. Service/maintenance and remanufacturing are also in particular focus in literature on PSS design and PSS design methods (e.g., [17, 23, 24]). The importance of information being available and the quality of such information both for remanufacturing and design departments have also previously been highlighted [25, 26].

In "Levor," despite the fact that remanufacturing is part of the PSS offering, there is currently only little information fed back to the design department from the remanufacturing facility. This feedback is not formalized at this point. The pathway shown in Fig. 2 is therefore not nearly as established as the consideration for customer requirements and the coordination with manufacturing. None of the interviewees mentioned remanufacturing as an important input to the design process, and the feedback stream shown was only named after a specific question by the interviewers. Further, the discovered feedback track also collects information from many other actors, further increasing the likelihood of remanufacturing-related information being buried by feedback from more established stakeholders. Due to this, issues that regularly occur when products used in PSS are being remanufactured have a much lower chance of reaching the design department and having an impact on design. A similar observation has been made assessing the information feedback and use of information provided by service and maintenance staff in [9]. The feedback processes from these actors are less formalized than, e.g., those concerning manufacturing, which may lead to a lower prioritization of these issues. In effect, the historically strong product focus of companies transitioning from being a product to becoming a PSS provider continues to be strengthened, inhibiting a profound transition.

From the findings presented, it can be deduced that the lack of a direct information pathway from key internal stakeholders benefiting from good PSS design (such as remanufacturing or service/maintenance divisions) may lead to reduced incentives to adapt existing design processes.

4.3 Managerial Focus and Product/Service Integration

Organizational changes undergone by companies when bringing integrated offerings of products and services to market are a widely researched subject. Observations made during an extensive project aimed at testing and implementing a PSS design methodology [27] at "Navitas" have shown that not only bringing PSS to the market initially but also the continuous development toward a higher integration and better utilization of PSS benefits (see Sect. 3) is highly dependent on relationships between service and design divisions, as well as management.

In 2007, [28] stated that in order to succeed in offering integrated solutions, managers of previously product-focused companies should "Create independent business unit to get focus while still maintaining strong links to line organization – top management's support needed" (pg. 75). The experience of evaluating [27] at a

machine manufacturer shows that this statement also holds when integrated solutions are already brought to market. Further, as early as 1999, [29] identified a need for a change in organization and corporate culture in order to successfully market sustainable offerings comprised of products and services. In addition, [3] has identified the close integration of product and service organization as a key aspect in allowing the economic benefits created by services to be transmitted to the manufacturing organization, in order to drive manufacturing and design changes with a PSS perspective.

The main challenge during the evaluation of the PSS design methodology at "Navitas" was to be found in the organizational separation of product and service development and the relationship between the different divisions. Historically, the product design division was less inclined to support the implementation of new design methods aimed at embracing the changes that offering PSS brings about. This may also be due to a lack of understanding of the possible benefits of a fully PSS-oriented design approach: This resounds the findings of [30], according to which manufacturing organizations often do not understand the benefits of higher reliability and maintainability, so long as competitors are not superior in these fields. As "Navitas" is successful in its business area, this may be an aspect leading to a lack of support for a full integration of PSS in design processes, particularly from a product design perspective.

The deployment of an integrated design method for PSS was also hampered by the substantially differing size of the design and service divisions. The employees involved with the evaluation of the PSS design method pointed out their satisfaction with the method in general, although they remarked that the complexity of such a method is a hindrance to implementation in an industrial environment. This points back to the fact that it is likely that the methods available are in part at fault for this issue, as discussed extensively in [8]. At the end of the evaluation process, the results were communicated to senior management staffs, and a modular implementation was suggested in order to cope with the complexity problem. Among management, a strong product focus could be perceived. It has previously been described that senior managers lack detailed knowledge about design and innovation processes in product design [31]. This may be a further aspect that can pose a hindrance to implementing a PSS design method.

Overall, insufficient managerial support and strong product focus as well as the operational and strategic separation of product and service design organizations led to no immediate changes in development processes. In addition, the benefits of the proposed method were not communicated to management in a way that would have warranted a stronger focus on the implementation of the method (e.g., cost-benefit calculations, new KPIs).

Table 1 Summary of key findings of possible causes of lacking adaptation of design processes to PSS

Possible causes for not implementing PSS design	Related literature
Customer pressure and incentives	[6, 21]
Reduced customer pressure toward process adaptation; this results from the responsibility shift between customer and PSS provider (Fig. 1)	
Previous customer requirements (efficiency oriented) have not been internalized by the provider side	
Stakeholder impact on design	[3, 9, 14, 25, 26, 30]
Lack of involvement of key internal stakeholders in PSS design process: remanufacturing and service	
Less formalized feedback processes	
Lack of time to develop a relationship as existing between manufacturing and design	
Management view and integration of product and service organizations	[6, 28, 29]
Persistence of a strong product focus	
Imbalance between product- and service-oriented divisions (financial, power)	
Lack of understanding of current processes and benefits of PSS design by management staff	

4.4 Summary

Within this section, a number of possible reasons for companies not to adapt their processes to PSS design were identified, and their general applicability was discussed with respect to literature. In Table 1, the information gathered is presented in condensed fashion in order to facilitate discussion and to allow industrial practitioners to get a concise overview of the challenges identified.

5 Discussing Effects of Not Adapting Design Processes to PSS and Potential Solutions to Bridge Existing Gaps

In this section, business- and environment-related effects of the identified hindrances for design process adaptation to PSS are discussed. Further, possible solutions, which may support the clarification of PSS design benefits and may drive practitioners to more readily adapt their processes, are presented. In addition, the impacts of these findings within the case companies are briefly reported.

5.1 Business-Related Matters

5.1.1 Capturing Lost Value Creation Opportunities

Due to the customer requirements shifting away from efficiency and concentrating largely on effectiveness, as described in Sect. 4.1 and Fig. 1 of this chapter, there is a chance of a significant part of the value creation opportunities to be lost. Traditional product-oriented design processes are not fit to capture the value contained in an increased effectiveness, if requirements are not set by the customer side. Thus, the opportunities brought about by the business model change, namely, to make use of the value of an offering optimized for efficiency, may go unnoticed. Although processes are in place to take in customer requirements for offerings to be designed, there are no processes that assist with internalizing previously external requirements and the associated value creation opportunities that arise from offering highly integrated PSS.

In order to increase the understanding of practitioners for these transfers of value creation opportunities, the concept of provider value may be viable [32]. Through this, additional possibilities to gain value beyond monetary value alone can be identified in direct relation to product and service components and different stakeholders. Further, provider-oriented quality function deployment (QFD), focusing particularly on processes taken over that were previously handled by customers, may be a viable approach to internalize previously external value-related aspects (see, e.g., [33]). Within large industrial companies, internal divisions may have customer/provider relationships to one another [9], suggesting the viability of an internal QFD process. Further, methods such as PSS-focused LCC [34] may help with grasping the lifetime cost of included components, leading to a broader understanding of the entire product life cycle.

Overall, it should not be forgotten that also the implementation of customer requirement-oriented processes in the past decades was neither simple nor painless for most organizations [35], indicating that time is also a key factor when transitioning to PSS-focused design processes.

5.1.2 Supporting Product and Service Design for PSS

Particularly the low impact of stakeholders that are dependent on good PSS design can lead to design decisions that may be adversarial to the performance of products and services within the offering. As mentioned in Sect. 4.2, the integration of customer requirements and the increasing collaboration between design and manufacturing departments have led to notable advancements in product design and customer value. Similarly, a close collaboration between the beneficiaries of PSS-oriented design processes (here identified as service/maintenance as well as remanufacturing departments) would likely lead to a substantial improvement in the performance of offerings in the use and end-of-(first)-life stages of the life cycle of a

PSS. This may be achieved, e.g., through direct delegates from these divisions who are involved in decision-making processes in the design stage of PSS development.

In order to be able to implement such a cooperation, creating a deep understanding of the relations among the actors and systems involved in the provision of offerings may be a suitable first step, as this often differs from the perception official documents may give [9].

A strong focus on life cycle considerations that spans the entire development process is naturally a very important aspect when seeking to improve the utilization of the benefits PSS can offer [36]. In integrating Service CAD [37] and life cycle simulation, [38] presented a tool which could be of great value in this regard. In a similar approach, [39] presented an illustrative tool developed to visualize life cycle value in computer-aided design (CAD) systems. [8] state that particularly tools like these, which do not substantially alter existing processes and are fit to bring about gradual changes, may be successful in steadily shifting processes toward a better integration of PSS design principles.

5.2 The Environment and Its Relevance for Future PSS Provider Success

As [4] states, "PSS is not the sustainability panacea," mainly the issue of dematerialization and reduced resource use is mentioned in literature as a cornerstone of PSS [2, 3]. Quantifiable data verifying the environmental benefits of PSS has long been lacking [4]; however, results have recently been published underlining efficiency benefits of PSS over traditional product sales offerings [15]. Nonetheless, thoughtful and integrated design of products and services from the earliest stages of development is essential in order to have the ability to obtain these benefits [7]. In line with findings in PSS-oriented literature discussed above, fully integrated design of products and services, aimed at efficiency and high customer value, will benefit providers, customers, and the environment. When discussing the matters found from a perspective of moving toward a circular economy, the environmental aspect may rightfully be the one given a maximum weight and importance. Nevertheless, in the reality of a growth-oriented economy, the topic of efficiency and dematerialization carries a profound implication, particularly for the provider side: Even though some countries are beginning to succeed in reducing the resources used within their economies, overall, resource use is still increasing substantially with every passing year [1]. As PSS are hoped and expected to play a significant role in moving toward a circular economy [4], the coming resource scarcity may very likely shift optimized efficiency from currently being a strong incentive for *additional* provider value to becoming a *matter of surviving* as a provider in an increasingly competitive market environment. For a more and more dematerialized economy, which creates sufficient value to allow all to pursue a life with no poverty and without deteriorating the base of our existence, highly efficient and integrated

offerings are needed. A strong focus on matters of resource efficiency, dematerialization, and the environment is becoming increasingly crucial for producing companies. How quick they are on the uptake on these matters may have a noticeable impact on their medium-and long-term performance.

5.3 Outcomes Within Companies

Together with the observations and deductions presented here, next steps have been planned at the participating companies to further examine and possibly alleviate the presented causes for an underdeveloped adaptation of design processes to PSS design paradigms.

Within the ongoing project at "Levor," ProVa (Provider Value Evaluation [32]) and Actors and System Maps [9] will be evaluated for their feasibility and usability as learning tools to enhance the general understanding of current processes and possible adaptations needed. Further, a possible adoption of the methods through the company will be assessed. These efforts will focus particularly on design for remanufacturing, which may likely lead to improvements for the PSS offerings in general.

At "Navitas," the evaluation of the PSS design method with support from researchers was concluded without management deciding upon an immediate implementation plan. However, the need for adaptation of processes was understood – as a result, a new position for evaluating and further pursuing the integration between product and service as well as the development of integrated offerings has been filled.

6 Concluding Discussions and Further Research

The cases of the companies "Levor" and "Navitas" on first sight appear as curious anomalies. Seemingly without substantial adjustments to design processes, which, according to literature [5–7, 13], are seen as critical for the success of PSS offerings, they have managed to become successful in offering PSS that deliver high customer value. Based on experience and information gathered during projects with the two companies, this chapter has discussed this paradox: Companies start offering PSS without a substantial adjustment of their design processes – and nonetheless they are successful. Can we therefore cease all research on PSS design and continue with "business as usual"? Based on the results of the research presented, the answer is a firm *no*.

Departing from an understanding of two companies' design processes and internal relations when developing products and PSS, possible causes for the absence of an adaptation of existing design processes to PSS offerings were

identified. Subsequently, potential results of the non-adaptation of design processes were discussed and viable solutions to the respective challenges examined.

Although the causes for non-adaptation of processes/non-adoption of PSS design methods may be individual and dependent on the circumstances within the respective company, generalizations were possible based on the literature identified and introduced throughout the chapter. Further, the solutions suggested can be useful even if the particular causes are not found within a company or if the identification stage is simply skipped due to a lack of an external audit (e.g., through researchers, consultants). It must be assumed that this outsider's perspective and neutral position toward the case companies have been helpful in identifying the challenges presented.

Overall, particular focus should be brought to the environment- and efficiency-related issues identified. Currently, these may serve as added value, as the companies and their success appear to rely on their technological aptitude and superiority in the marketplace. However, as resources are becoming scarcer, maximum efficiency will likely transition from being an *added benefit* or provider value to becoming a *necessity* to remain on the market. Taking steps toward attaining this goal by developing and implementing design processes that integrate products and services, have a true life cycle perspective, and are concentrated on effectiveness and efficiency *now*, out of a position of strength and success, appears much more promising than a forced transition out of pure economic necessity *tomorrow*, when the room for error is much diminished.

As indicated in Sect. 5.3 in the coming months, the usefulness of the proposed methods to identify, communicate, and address the detected challenges in adapting existing design processes to PSS will be evaluated in industrial practice. Further, their usefulness in conveying hitherto unutilized PSS benefits within companies' offerings will be assessed and presented in a future publication.

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