An integrated lifecycle model of product-service-systems

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Abstract

Managing today's innovation processes becomes increasingly difficult due to higher dynamics and complexity along the PSS lifecycle. To be able to consider dynamics along the lifecycle early in the innovation process, an integrated understanding of the PSS lifecycle is crucial. Therefore, this paper addresses a PSS lifecycle model considering phases from the planning and development of PSS throughout the phases of use and disposal. The lifecycle of the physical component (product) must thereby not be seen separately from the associated service lifecycle. Based on existing lifecycle models in the areas of service engineering and integrated product development, an aggregated PSS lifecycle model is deduced and discussed.

Keywords

Lifecycle, Innovation Process, Dynamics, Integrated Product Development, Strategic Planning

1 INTRODUCTION – AN INTEGRATED LIFECYCLE MODEL OF PRODUCT-SERVICE-SYSTEMS

1.1 Motivation

Companies in industry face the fundamental challenge to improve their innovation processes in order to cope with the increasing complexity of today's products and corresponding services. Against this background, it is essential for companies to frontload an integrated systems understanding to the early phases of planning future product-service-systems (PSS). In particular changes and corresponding change propagations along the future PSS lifecycle have to be considered early in order to prevent unnecessarily provoked lifecycle costs, which grow exponentially the later unintended changes are made within the lifecycle [1]. In this context, it is essential to anticipate the whole lifecycle of future PSS in order to allow fast responses to influences from the environment and moreover to adapt the portfolio of offered products and services as well as corresponding company processes to the latest conditions with regards to content and time [2, 3]. To be aware of interrelations within the lifecycle and its phases in a first place a sophisticated understanding of the lifecycle phases, a PSS runs through, is needed. In the past the lifecycles of products have been researched a lot, in particular in the areas of engineering design and product lifecycle management. Also service lifecycles have been discussed, especially in the last few years. But in order to plan future PSS in an integrated way, a separate perspective on the product and service lifecycle is not sufficient. Therefore, in the past years, first approaches in respect to an integrated PSS lifecycle understanding have been established. E.g. the research project TR29 [4] presents a framework of dealing with information along the PSS lifecycle. Nevertheless, there is still a need for a PSS lifecycle model which is suitable for describing interrelations along the lifecycle at a reasonable level of granularity in the early phases of planning future PSS.

1.2 Background of research

Research presented in this paper is carried out against the background of the collaborative research centre "SFB 768 Managing cycles in innovation processes". Within the SFB 768, participants of social, economic and engineering sciences follow the goal of supporting engineers and other stakeholders along the innovation process in dealing with the heterogeneous temporal behaviour of artefacts (cycles) within the innovation process. For example, cycles can be detected in respect to usable technologies, as company-relevant technologies in the competitive environment (suddenly) emerge, evolve, get obsolete, get replaced by another emerging technology which evolves, and so on. In order to be able to manage these cycles throughout the innovation process, it is important to already consider these cycles when planning future PSS. In this context, it is essential to anticipate changes in respect to the potentials and constraints along the lifecycle in order to launch product-service-systems which fulfil customer needs but at the same time fit into the processes and possibilities of the PSS-providing company. Furthermore, changes within the singular phases of the PSS lifecycle may impact changes in other lifecycles phases, which are not obvious at a first sight. In order to describe possible change propagations along the lifecycle, a detailed understanding of lifecycle phases and their interrelations is needed. Thereby, the question arises, which lifecycle phases are run through by a PSS. Where in the PSS lifecycle are tasks concerning the product being carried out separately from the service and where is an integrated perspective obligatory?

Thus, this paper presents an integrated model of the lifecycle of product-service-systems throughout the phases of planning, designing, delivering/using and decomposing PSS – deduced from various lifecycle literature in the disciplines of engineering design, service and PSS engineering. In section one, different lifecycle models in product, service and PSS engineering are discussed and compared. Based on this literature review, the process of aggregating an integrated PSS lifecycle is described and the integrated PSS lifecycle model is presented. Thereby, not only the singular phases the PSS runs through are shown, but also specifics in dealing with the lifecycle model are explained. Finally, conclusions are drawn and an outlook on future research based on the reference model of the PSS lifecycle is given.

2 EXISTING SERVICE, PRODUCT AND PSS LIFECYCLE MODELS

In this section, an overview about existing lifecycle models in service, product and PSS engineering is given. The models, identified and explained in the following, describe the basis for the aggregated PSS lifecycle model in section 3.

2.1 Service lifecycle models

A first existing approach, presented in the context of modelling the service lifecycle has been researched by Schwarzer [5]. This model consists of the phases 'Idea generation and evaluation', 'Requirements', 'Design', 'Implementation', 'Service delivery' and 'Replacement'. Another model – deriving from service engineering science – which is comparable to the model of Schwarzer is discussed by Meiren und Barth [6]. It also consists of five superordinate phases. Each of the phases is split down to several submodels, which have to be considered within each phase (see Figure 1). Bullinger et al. [7] consider similar phases in their model, but further add the phase of 'Post-launch review' in their waterfall model.

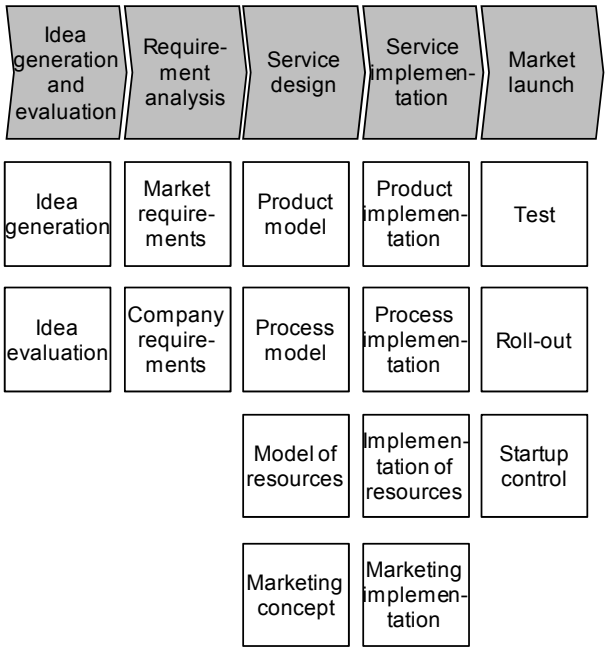

Figure 1: Service lifecycle model according to Meiren and Barth [5]

Another model describing the service lifecycle is presented by Ramaswamy [8]. In this model, a feedback loop specifically emphasises the importance of improving the service after measuring the performance and customer satisfaction. When improving the service, the lifecycle is run through again and thus the lifecycle is shown as a loop. A very similar model to Ramaswamy's one is presented by Cernavin et al. [9].

Besides the above mentioned aspects within the service lifecycle, Krallmann and Hoffrichter [10] also consider a phase of looking at already implemented services in order to evaluate new service ideas.

A very detailed lifecycle model of services has been researched by Schneider and Scheer [11]. Their 'Customer related Service Life Cycle (CurLy)' is divided into the superordinate phases:

- Start-Up-phase
- Concept-phase
- Implementation-phase
- Monitoring-phase

Each of these superordinate phases is detailed by many subphases. E.g. within the phase of 'Monitoring', the 'Customer Relationship Management' is explained in order to tie the customer to the company.

Although there are far more models concerning the service lifecycle, these are not further explained due to their similarity with the already explained models. Thus, following discussions in section 3 in respect to an aggregated PSS lifecycle model are based on the presented literature.

2.2 Product lifecycle models

Within the research project SFB 768, a reference model of the product lifecycle with respect to further use in the context of supporting strategic planning has already been established and published by Hepperle et al. [12] (see Figure 2). Thereby, the model has been deduced on the basis of various existing lifecycle models in product lifecycle management [e.g. 13-16] and engineering design [e.g. 17-20]. As this lifecycle model provides an ideal basis and will therefore be used for discussing an integrated PSS lifecycle model in section 3, the major aspects of the model and according literature are shortly presented in this section.

The lifecycle model consists of the superordinate phases of 'Product planning', 'Product development and design', 'Production process preparation', 'Production', 'Distribution', 'Utilisation', 'Maintenance', 'Modernisation lifecycle' and 'Product disposal'. Thereby, the phase of product planning has been detailed based on VDI 2221 [17], VDI 2220 [21] and Braun [22]. In this phase, product ideas are generated and prioritised based on the market needs and the company potential before a product recommendation is handed over to the next lifecycle phase. The 'Product development and design' is particularly based on the 'Munich Model of Product Concretisation' by Ponn and Lindemann [23], VDI 2221 [17] and Hundal [24]. Thereby, requirements are continuously updated, while the product gets more detailed by defining the product functions, the working elements, the components and their structure before building and testing the prototype. The phase of 'Production process preparation' is mainly described based on literature by Arnold et al. [13], Gausemeier et al. [25] and VDI 4499 [26]. As there is a high number of different manufacturing and assembly techniques, the phase of production is reduced to the three steps of manufacturing, assembly and test of the product. These phases are mainly described based on Ehrlenspiel [19], Gausemeier et al. [25] and Conrad [27].

The next phase 'Distribution' consists of the steps packaging and warehousing the product, delivery and possible intermediate warehousing of the product. These steps are deduced from Kleinaltenkamp and Plinke 1995 [28]. Within the following phase 'Utilisation', it is emphasised according to literature by Ullman [20] to consider multiple periods of utilisation. In this context, the modernisation / upgrade of products is based on the discussion of Mörtl [29], also baring the phase of recycling in mind according to VDI 2243 'Recycling-Oriented Product Development' [30].

In parallel to the phase of utilisation, major tasks concerning the maintenance of products are shown according to DIN 31051 [31]. After the phase of utilisation, the product lifecycle ends with the 'Product disposal and recycling'. After shutting down and disassembling the product, components are disposed or recycled according to VDI 2243 [30] and Stengel et al. [32].

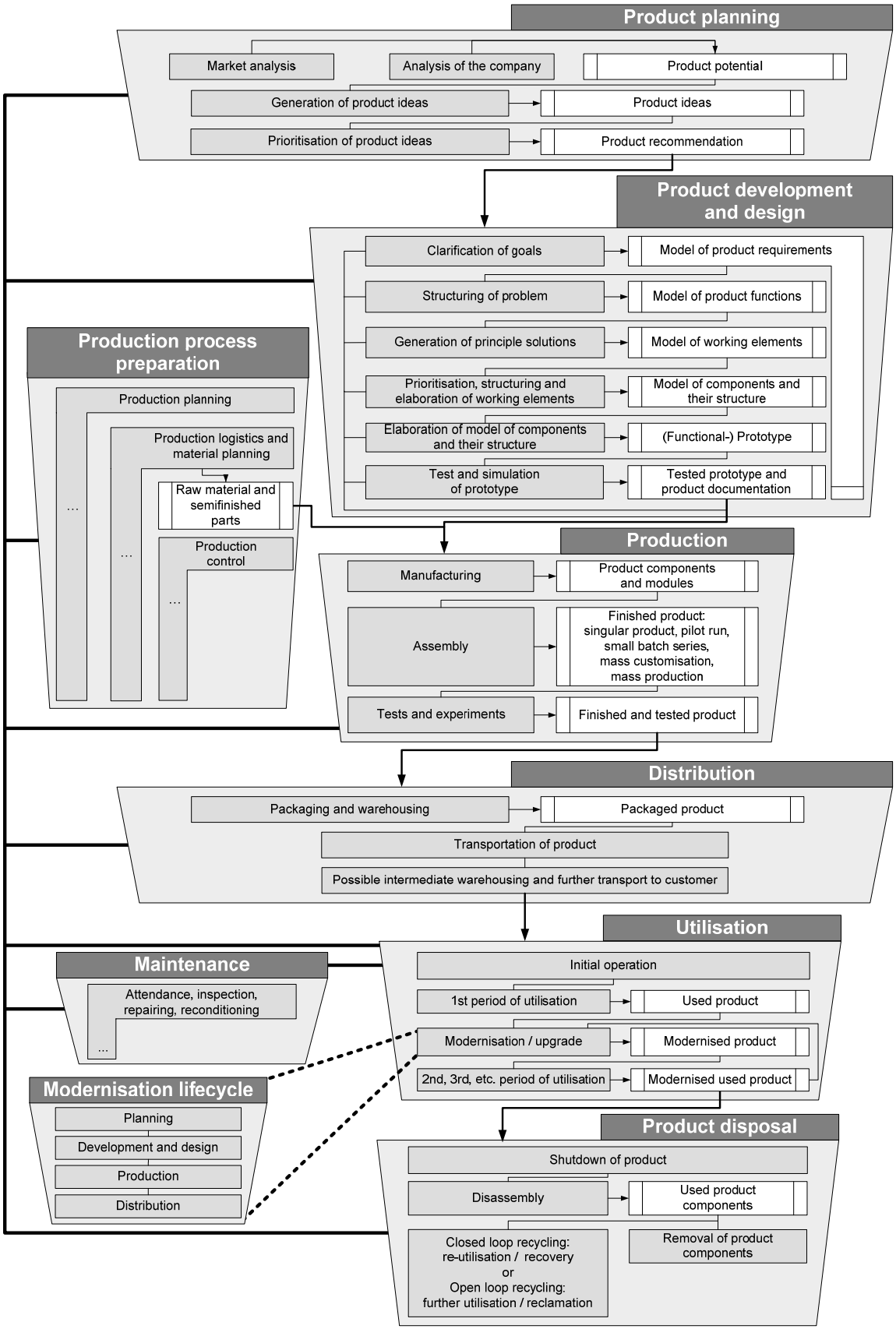

Figure 2: Product lifecycle reference model according to Hepperle et al. [12]

2.3 Preliminary work concerning lifecycle models of product-service-systems

Besides the isolated perspective on products and services, also first approaches in dealing with the lifecycle of product-service-systems have been researched. For example, Becker et al. [33] discuss a framework of hybrid value creation. The lifecycle of PSS is thereby split up into the superordinate phases of design, delivery and replacement. Around these core processes, they describe supporting, coordinating, supply and sales processes.

In the lifecycle model of Hartel [34] only five product related lifecycle phases 'Research', 'Development', Production', 'Utilisation' and 'Disposal' are shown. In this model the PSS-perspective comes in, as various services are assigned to the product phases. Thereby, Hartel distinguishes between 'Pre-sales', 'Sales' and 'After-sales' services. This differentiation can also be detected in the work of Knackstedt et al. [35], who research product accompanying services.

As already mentioned in the introduction, the collaborative research centre TR 29 also discusses product-service-systems. Within that research, e.g. Abramovici and Schulte look at the PSS lifecycle both from the company's and the customer's perspective [36]. Thereby, the model is not too detailed, as in the first place it tries to give an initial picture how the lifecycle management, i.e. the information flow throughout the lifecycle can be arranged.

Another reference to mention in the context is delivered by Aurich et al. [37]. Thereby, besides introducing phases of the technical service design process, they provide a 'concept of process modularization'. This concept focuses on linking product and service design processes but also bearing the flexibility in mind which is necessary to consider individual demands in the extended value creation network.

The presented references rather help to understand the integrative perspective on PSS or focus how to deal with the different data throughout the lifecycle. As the provided information is not sufficient for getting a more detailed overview of aspects to be considered in the early planning of PSS, an aggregated PSS lifecycle model with an appropriate detail level is deduced in the next section.

3 AN INTEGRATED PSS LIFECYCLE MODEL

3.1 Procedure of aggregating the PSS lifecycle

Mainly based on the mentioned references, an aggregated PSS lifecycle model is deduced in this section. Thereby, the PSS lifecycle model consists of phases which should necessarily be run through interactively, while other phases are run through separately in the product and service discipline, still baring the continuous communication between the disciplines in mind.

In the area of more product related aspects of the PSS lifecycle, the product reference model according to Hepperle et al. [12] (see Figure 2) was used for the aggregation. This model is deduced from various existing literature in order to allow a detailed view on aspects relevant for early planning of products and therefore describes an appropriate basis for the product elements within the PSS lifecycle.

For considering service aspects within the integrated PSS lifecycle none of the existing models distinguishes itself to being directly taken over. Therefore, in section 3.2 a reference model of the service lifecycle is presented before the aggregated PSS lifecycle is explained in section 3.3.

Besides the considered product and service lifecycle, further issues have to be taken into account in order to emphasise the integration of the two disciplines. Therefore, the lifecycle model consists of elements, which are necessary to describe the interaction between product and service aspects within the lifecycle. These elements are described in section 3.3.

Finally, there are some issues to be considered when dealing with the presented PSS lifecycle model. These aspects are disclosed in section 3.4. In particular, the linkage to further considered aspects within the collaborative research centre SFB 768 'Managing cycles in innovation processes' are pointed out in order to classify the results concerning the integrated PSS lifecycle.

3.2 Aggregation of the service lifecycle

Before aggregating the model of the PSS lifecycle in section 3.3, a service lifecycle model for the further use is presented in this section. The model (see Figure 3) is particularly derived from the references by Meiren and Barth [6], Ramaswamy [7], Cernavin et al. [8], Krallmann and Hoffrichter [10] as well as Schneider and Scheer [11].

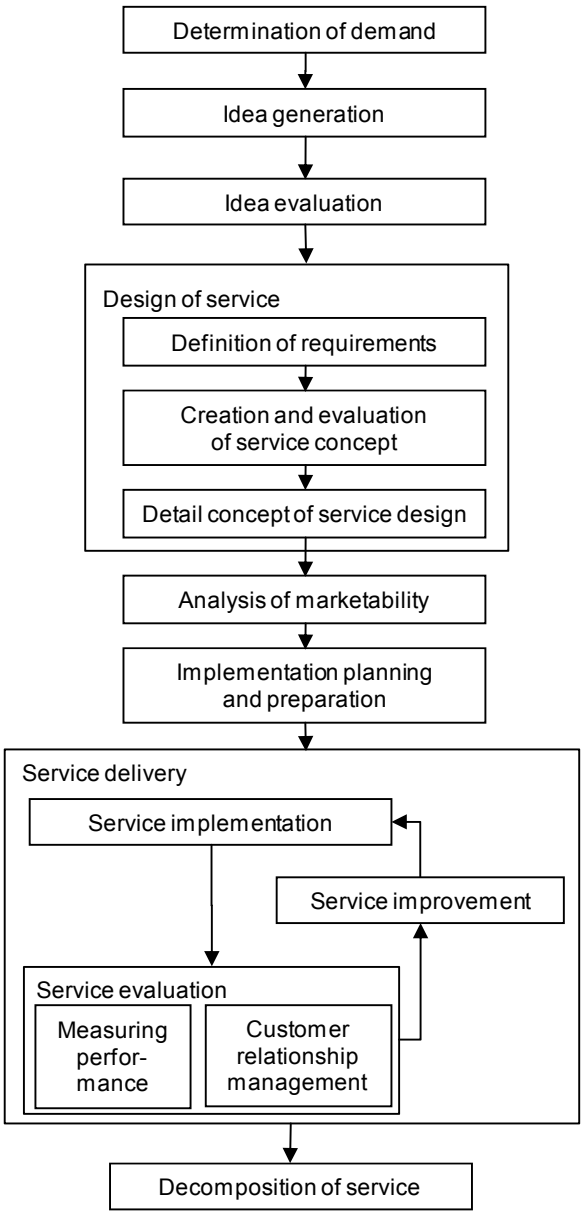

Figure 3: Reference model of service lifecycle

3.3 Aggregation of the PSS lifecycle

As already mentioned, the integrated lifecycle model of PSS (see Figure 5) is predominantly deduced based on the product lifecycle reference model by Hepperle et al. [12] (see Figure 2) as well as the service lifecycle reference model presented in this paper (Figure 3). The aggregated PSS model consists of the three major parts:

- PSS planning
- PSS development
- PSS production, delivery and decomposition

Thereby, the model consists of PSS states and PSS working phases. From the PSS planning to the PSS

development, an integrated PSS-development suggestion is handed over. Similarly, from the PSS development to the PSS production, delivery and decomposition, the designed PSS is transferred.

Within each of the superordinate phases, tasks can be performed integrated (e.g. PSS planning) or being solved partly separately, bearing a continuous communication between the disciplines in mind (e.g. PSS development).

In a first step, PSS potentials are deduced from environment and company potentials and PSS ideas are generated and evaluated according to these potentials. Based on the PSS development suggestion, it is necessary to decide whether and to which extent the offered solution is being carried out by a service or by a product element. In the next step, requirements both for the product and for the service are gathered. The requirements are regularly updated during the design process and thus, a continuous communication between the product development and the service design department is essential for the later success of the PSS. After both product and service elements of the PSS are finally designed, a test of marketability shows, whether the PSS is ready for being launched and delivered to the market.

While the product is produced in the next steps, it is important that the service implementation is prepared. Thereby, supporting tools have to be finalised. Already around the phases of distribution, singular product accompanying services can be delivered (Pre-product-use-services). This can for example be a service concerning the transport of the product. During the phase of using the product, further services may be demanded within the customer's solution (Services during product use). Such services may be attributed to a modernisation or maintenance contract. Particularly for the case that a product upgrade is performed, the service has to be adapted. Therefore, a communication between the adaptation / improvement of the service and the modernisation lifecycle of the product is necessary. Also services, concerning the phases of 'After-product-use' are considered within the integrated PSS lifecycle model. These kinds of services may e.g. concern the shut-down of the product as well as the redemption of product components. For all kinds of services, the same 'Service delivery' is run through.

As it is not shown in Figure 5, one should bear in mind that some services – in particular those corresponding to the after-product-use phase – cannot finally be designed before the PSS is launched. E.g. for products which stay at the customer for more than 30 years, it may not be possible to already consider how the respective product can be disposed. Thus, the detail service design has to be finalised while the product is already on the market. Nevertheless, a first concept should already be taken into account in the early stage of the PSS lifecycle in order to have an integrated concept and in order to provide potentially necessary interfaces at the product.

Furthermore, not all tasks have to be performed by one company. E.g. the company offering the PSS may outsource the production of the product. In addition, not all of the phases have to be run through compulsory.

3.4 Additional considerations

The integrated PSS lifecycle model gives an overview about the different phases and can therefore be seen as a checklist, which aspects may already be considered in a lifecycle oriented planning of PSS. When planning future PSS, it is of interest, how the PSS of the future has to change compared to the currently offered PSS. Thereby, changes within the lifecycle from PSS to PSS may derive from manifold sources and according context factors. Changes can originate both from the environmental, market and company background.

Different factors, which can be assigned to manifold areas both concerning the side of 'purchases' as well as the 'sales' side, can be detected based on the research by Langer and Lindemann [38] (see Figure 4).

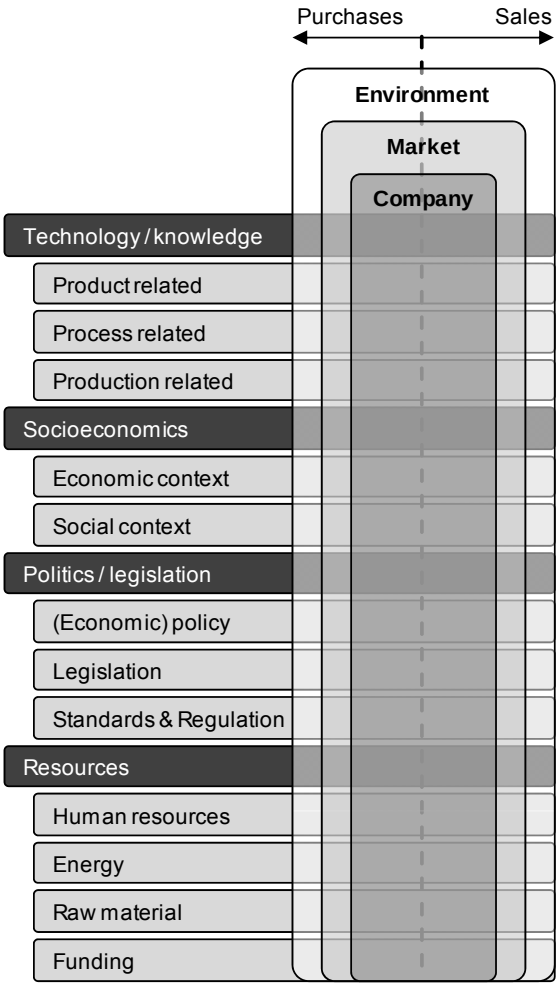

Figure 4: Context factors of product development according to Langer and Lindemann [38]

As these context factors are often characterised by dynamic behaviour, the influenced PSS lifecycle also shows dynamic behaviour. Thus, it is of interest, which factors within the different categories influence the different lifecycle phases and how the impact on the lifecycle phases looks like. Furthermore, by identifying interrelations between the lifecycle phases, it will be possible to setup chains of cause and effect by increasing the transparency of change propagations within the lifecycle.

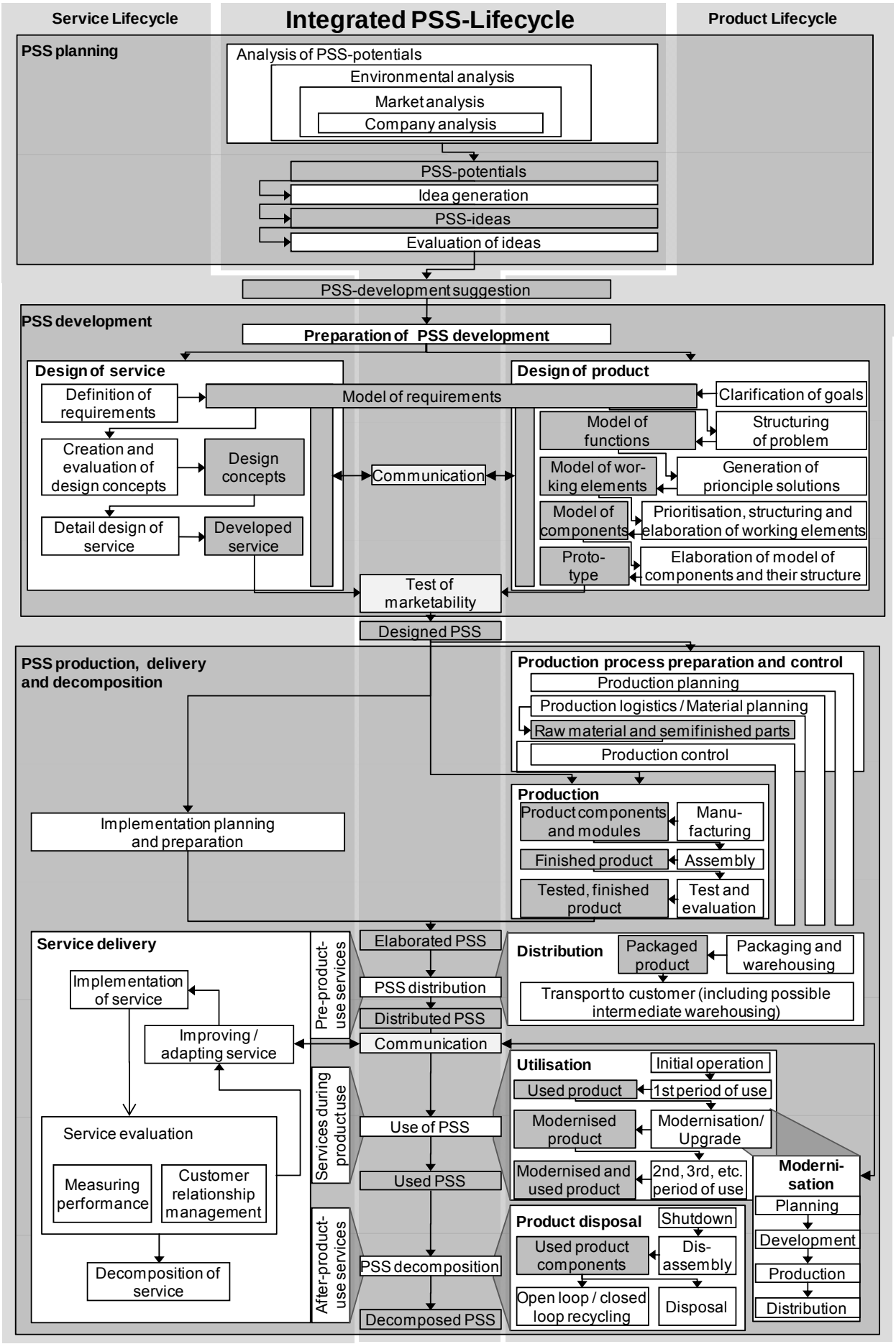

Figure 5: Reference Model of integrated PSS lifecycle

4 SUMMARY

4.1 Conclusions

Based on various existing literature, a reference model of the PSS lifecycle has been presented in this paper. Thereby, the model was aggregated with the goal of getting an appropriate basis for further analyses concerning a lifecycle oriented planning of PSS.

In comparison to other existing PSS lifecycle models, which are still very rare in literature, the presented model followed the purpose to be detailed enough but still manageable to overview the singular phases a PSS runs through.

Against that background, a major focus of the research was to share an integrated perspective on the PSS lifecycle. On the one hand, that means that all lifecycle phases from the early planning of PSS until the later phases of utilisation and decomposition of products and corresponding services have been taken into account. On the other hand, it means that throughout the lifecycle, the strong interaction and integration in dealing with the PSS have been emphasised.

Despite the limitations of a generic approach to describe the PSS lifecycle, it still allows an overview about singular tasks and PSS states along the lifecycle. Further, the model itself provides a valuable input for further work, which is presented in the final section.

4.2 Outlook

Until now, the aggregated PSS lifecycle model is particularly based on literature, but also on industrial experience. Thereby, on the one hand discussions with different industrial partners from automotive industry as well as from a company developing and producing 'white goods' and household equipment have been reflected. On the other hand the authors' experience from working in different industrial projects has been considered in deducing the PSS lifecycle model.

Furthermore, the model has been validated successfully based on simple examples. Nevertheless, in order to validate the results in depth, one of the next steps will be to evaluate the model based on a case study. For this evaluation, interviews which are currently conducted will also be taken into consideration.

As section 3.4 has shown, one important step in researching the dynamic behaviour of subsequently following lifecycles will be to assign the factors, influencing the PSS lifecycle, and the corresponding identified cycles to the singular phases of the lifecycle. This will support the transparency in respect to lifecycle oriented planning of PSS.

Another focus of further work is directed on interrelations between the singular phases of the PSS lifecycle. A more sophisticated understanding of those interrelations will help to support the understanding of general and company specific change propagations within the lifecycle of product-service-systems.

For the identification of interrelations, an extended analysis of 'Design for X' [39] guidelines will be performed. This approach to identify interrelations within the product lifecycle has already been successfully tested in a first step. Thus, this analysis will be extended, now also taking guidelines like 'Design for service' into account [40]. In parallel, a framework of how these interrelations can be classified and further analysed is built up based on previous work from Maurer et al. [41].

5 ACKNOWLEDGMENTS

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