TEMPORAL ASPECTS IN LIFECYCLE-ORIENTED PLANNING OF PRODUCT-SERVICE-SYSTEMS

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In order to cope with the increasing complexity of today's products, companies face the fundamental challenge to share an integrated perspective on the lifecycle of products and corresponding services (product-service-systems) to allow fast responses to influences from the environment and moreover to adapt the product portfolio and corresponding company processes to the latest conditions with regards to content and time. Thereby, different temporal aspects have to be taken into consideration according to the different planning horizons. In this paper, firstly temporal constellations considering the singular phases of the PSS lifecycle as well as the whole PSS lifecycle are discussed. Further, the importance of understanding the temporal patterns of factors influencing the PSS lifecycle is highlighted. Finally, it is reflected upon the planning frequency of companies considering different planning horizons within the given context of temporal lifecycle patterns.

Keywords: Product planning, Product-service-systems, Lifecycle, Temporal patterns, Dynamics.

1. INTRODUCTION — LIFECYCLE ORIENTED PLANNING OF PRODUCT-SERVICE-SYSTEMS

1.1. Motivation and research background

Manufacturing 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. In order to survive within that environment, the improvement of the innovation capability describes an essential lever to enhance the company‘s profitability and growth [1]. In this context, it is essential for companies to frontload an integrated systems understanding to the early phases of planning future products and corresponding services. Thereby, the focus is directed on product-service-systems (PSS), which are characterized by a highly custom-oriented value creation by systematically combining service and product components to solutions. PSS should thereby interactively being planned and developed, in order to coordinate the requirements for the product and service components from the beginning of the innovations process.

Accordingly, systematic planning of PSS in the early stages of the design process is essential. In this context, it is important 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].

One way to allow an integrated perspective on the content of future products comes in when pursuing a sophisticated understanding of the PSS lifecycle. Considering the phases from the development,

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the production, the distribution until the phases of utilization and recycling sharpens the systems understanding and thus supports the awareness of possible interrelations within the lifecycle. Taking those interrelations — as far as possible — already in the planning phase into account may support detecting goal conflicts in the early stages of the innovation process and thus may avoid changes along the lifecycle. This prevents from unnecessarily provoked lifecycle costs, which grow exponentially the later unintended changes are made within the lifecycle [4].

In the past, manifold research has been carried out in marketing science concerning factors influencing the acceptance of customers to buy and use a new product and according technologies. Especially the phases of utilization are emphasized in these so called technology acceptance models (TAM) [e.g. 5, 6]. Still, the importance of further lifecycle phases such as production or recycling are not considered in these approaches but also influence the future product to a certain extent. Furthermore, these technology acceptance models rather suggest relevant factors than showing how to deal with these factors within the context of utilization periods. These periods can easily reach for certain products — such as a car or a washing machine — 10 years and more, and thus, different anticipation approaches are necessary to deal with the different technology acceptance factors along the time axis. Expanding the marketing oriented perspective with focus on the utilization phase to an integrated lifecycle perspective, even further constellations along the time axis of the lifecycle become interesting. Although, anticipation of possible lifecycle futures is always characterized by uncertainty, reflecting upon temporal patterns around the anticipation of future products on the one hand helps to detect appropriate planning approaches for the different lifecycle phases. On the other hand it may give hints how to synchronize future product generations and according planning processes against the background of the dynamic environment, which may again be described by respective temporal patterns.

To be able to discuss temporal patterns — i.e. recurring sequences of phases — in the context of lifecycle-oriented planning of PSS, section one provides an overview about previous work and results gathered within the collaborative research centre “Managing cycles in innovation processes”. On this basis, Sec. 1 highlights fields of temporal aspects to be discussed in the Secs. 2 to 4. Section 5 summarises the discussed temporal aspects and finally conclusions are drawn and an outlook on further work is given.

1.2. Previous work

Research presented in this paper is primarily based on gathered results within the collaborative research centre SFB 768 (www.sfb768.de), which consists of researchers from mechanical engineering, economic and social sciences as well as business informatics. The focus of the research project is directed on the management of cycles in the context of innovation processes. Thereby, cycles are defined as recurring structural or temporal patterns. These patterns are characterized by respective phases, by a trigger, by an effect as well as by a certain duration. One focus within the research centre is on strategic planning of future product-service-systems.

An important aspect addresses the understanding of the context future product-service-systems and corresponding processes are embedded. Langer and Lindemann 2008 [7] synthesized a model based on manifold existing literature [e.g. 8, 9] how the context of factors influencing the development and design of PSS can be structured. The context model can also already be consulted in the even earlier phases of strategic planning, as the respective classes of context factors are the same for PSS planning and development. As the context with its surroundings, requirements (e.g. customer needs) and potentials (e.g. new technologies) is evolving, companies should be aware of the temporal behavior of key factors relevant for the respective context the company and its products and corresponding processes is embedded in. Thereby, the context model consists of the superordinate categories ‘Technology/ Knowledge’, ‘Socioeconomics’, ‘Politics/ Legislation’ and ‘Resources’. These categories are further subdivided, whereby factors can be detected both in the company, market and environmental context.

Besides structuring the context factors, it is important to understand mechanisms concerning the lifecycle of future products and corresponding services. Therefore, Hepperle et al. 2009 [10] deduced in

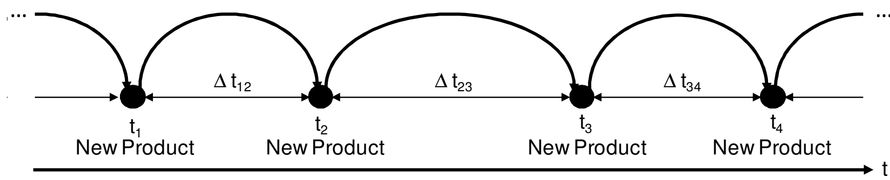

Figure 1. Cycle of launching new products [17].

a first step an integrated product lifecycle model which was deduced from various literature in product lifecycle management and engineering design. The lifecycle model consists of the superordinate phases of 'Product planning', 'Product development and design', 'Production process preparation', 'Production', 'Distribution', 'Utilization', 'Maintenance', 'Modernization lifecycle' and 'Product disposal'. These superordinate phases are further split down to more than 25 working phases and more than 15 product states. This model — in particular focusing on products — has then further been extended in respect to an integrated perspective on PSS lifecycles [11] (see Figure 2). Thereby, research concerning service engineering [e.g. 12, 13] as well as existing literature dealing with product-service-systems [e.g. 14, 15] has been considered. The importance of coordinating the product and service perspective throughout the lifecycle has been emphasized.

Both mentioned lifecycle models support the understanding of the phases a PSS runs through and thus describe an appropriate basis for lifecycle-oriented planning of PSS. Nevertheless, temporal aspects — such as the duration of singular phases as well the temporal coordination of lifecycle phases — need also to be understood in order to increase transparency concerning the lifecycle information when performing strategic planning and corresponding information handling.

Although there has already been research carried out concerning subsequently following lifecycles (e.g. concerning face-lifts [16]), the presented lifecycle-oriented perspective brings in further dimensions to increase the transparency concerning respective temporal constellations. Thereby, the combination of the lifecycle perspective with temporal patterns in launching new products (e.g. see Figure 1) is pursued.

The gap between two product generations in Figure 1 shows, how long one product generation is produced and delivered to customers. This period again impacts the planning horizon for one product generation. When planning further product generations, the planning horizon even expands. Concerning the strategic planning it is widely accepted that three different planning horizons can be distinguished [18]: short-term planning up to one year; medium-term planning from one to five years; long-term planning more than five years. Depending on the product, the planning horizon for different product generations is thus impacted both by the duration of the lifecycle and its singular phases as well as of the intention to anticipate requirements and potentials of further PSS generations along the product roadmap. Against that background, an interview series is currently carried out among different persons in industry which are part or at least closely linked to planning future products and corresponding services. Thereby, the persons were asked about the company's product planning process and in particular how the company deals with short-, medium- and long-term planning. Furthermore, they were asked in how far they take already the whole lifecycle of future products into consideration when planning the product roadmap.

1.3. Highlighted temporal aspects in this contribution and research procedure

As shown in the previous section, manifold fields can be researched with respect to lifecycle-oriented PSS planning. Against the presented background, this paper gives insight into three different fields, which are thematically interlinked.

First, Sec. 2 focuses **temporal aspects concerning the PSS lifecycle and its phases**. Different lifecycle constellations are presented for discussing both temporal aspects for a singular lifecycle and respective phases as well as for multiple subsequently following product generations. Research carried

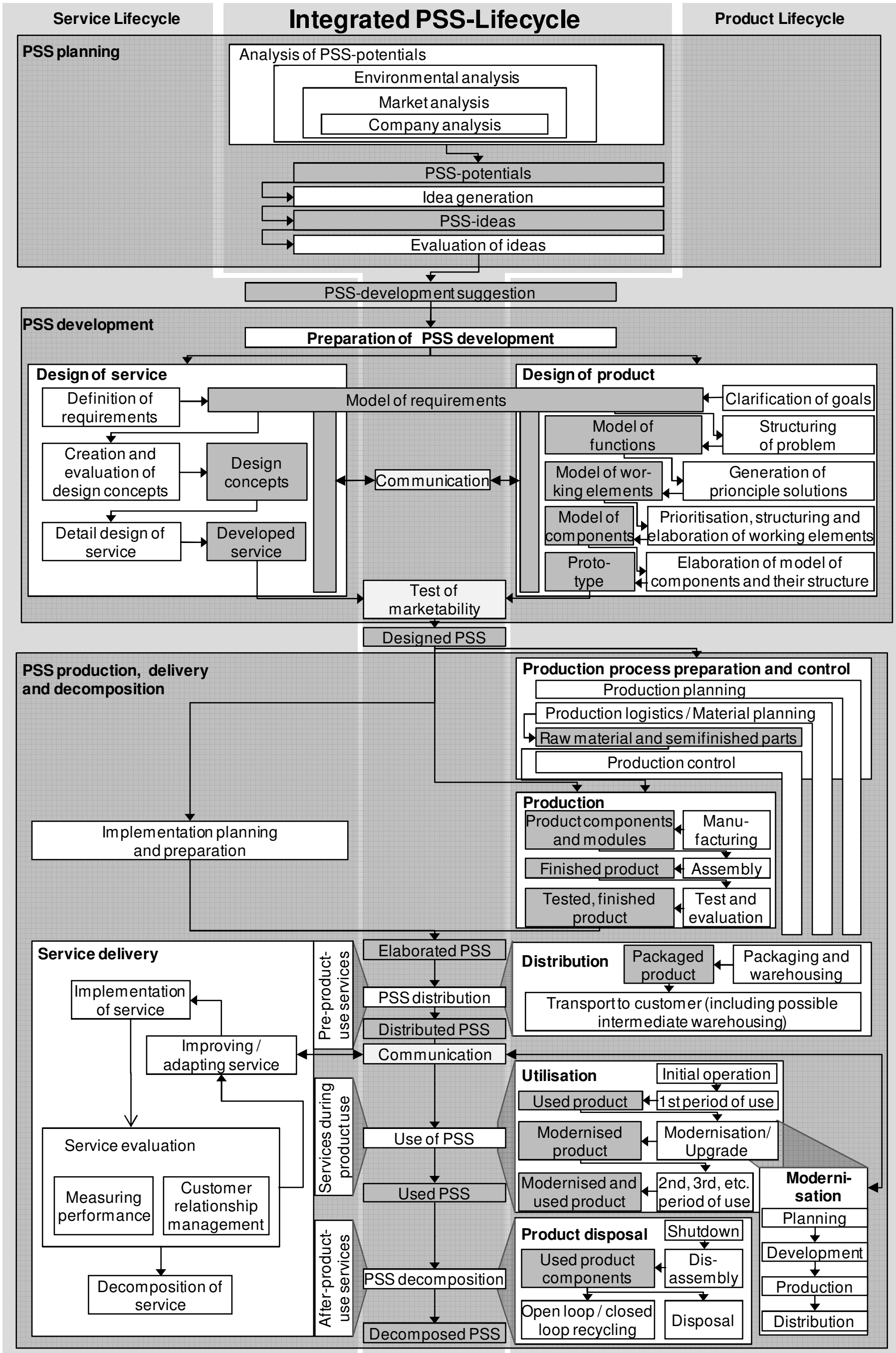

Figure 2. Integrated PSS lifecycle according to Hepperle et al. 2010 [11].

out is primarily based on experiences among the authors as well as on reflection of industrial practice. Although considerations are based on a simplified product lifecycle model, presented findings can widely be transferred to the more sophisticated PSS lifecycle model presented in Figure 2. Especially singular lifecycles of the manifold combined PSS elements (service elements, IT components such as software and respective IT hardware, product components) are not yet taken into account, but can be considered in future discussions based on presented results in Sec. 2. The understanding of respective singular lifecycles brings in further dimensions in coordinating the different PSS elements and thus contributes to create a higher level of customer satisfaction.

As the lifecycles and corresponding constellations presented in Sec. 2 are embedded in the company, market and environmental context, Sec. 3 then sheds light on the **temporal behavior of context factors** influencing the product and the corresponding lifecycle. Thereby, some examples from automotive technology back up, how patterns relevant for future innovations and corresponding lifecycles can be described. The examples as well as the description of patterns are derived from various articles dealing with automotive industry as well as literature dealing with respective time patterns.

In addition to temporal aspects concerning lifecycle patterns as well as the respective context factors of PSS planning, Sec. 4 reflects upon **temporal aspects concerning the planning process and according planning rhythm**. Based on qualitative findings in interviews it is shown, how industrial practice deals with various time horizons in the context of short-, medium- and long-term-planning.

2. TEMPORAL LIFECYCLE ASPECTS AND PATTERNS

2.1. Approach in discussing temporal lifecycle aspects

Concerning the discussion of temporal lifecycle patterns, a simplified product lifecycle has been used. It consists only of the four superordinate phases ‘Development’, ‘Production’, ‘Utilization’ and ‘Recycling/Disposal’. This abstraction is necessary in a first step in order to allow identification of planning-relevant temporal aspects concerning singular lifecycle phases, as well as lifecycle constellations of singular and multiple product generations. Figure 3 is the basic scheme for further analyses in this paper. Besides multiple product generations, also the industry-relevant topic of ‘face-lifts’ is embedded within the scheme. In order to better understand the mechanisms of one product generation, also the lifecycles of the first as well of the last produced product piece within a product generation are described.

The discussion carried out in the following two subsections leads to more transparency when planning the future product portfolio. Being aware of the temporal patterns may allow in a next step the identification and application of appropriate planning instruments e.g. in respect to different time horizons. Although the absolute time differs of course from branch to branch and from product to product, the general mechanisms can be applied to manifold branches and help to increase transparency of planned goods.

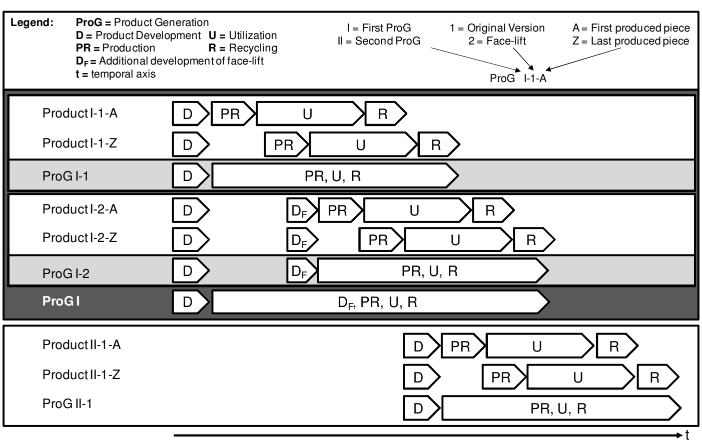

Figure 3. Scheme of multiple subsequently following lifecycles.

2.1.1. Temporal aspects concerning lifecycles of one product generation

At first it is mentioned that from every product instance to product instance, singular phases are characterized by its own length. Thereby, from a planning point of view, especially the duration of the utilization can differ from product instance to product instance. E.g. a car may be involved in an accident right after being sold, other cars of the same product generation may last more than 20 years on the market. This is in so far relevant for planning products, as the phase of recycling and disposal has to be considered within lifecycle-oriented planning from the point of time, the first car is being launched until the last car gets disposed. Another perspective — also influencing the duration of the utilization phase — comes in, when discussing upgrades and updates (modernization) within a product already used for some time at the customer.

Other phases — such as the development of one product generation — are run through together for the whole product generation. This makes the planning horizons for requirements and potentials concerning the development process more feasible in comparison to the time horizons concerning phases such as the utilization and the recycling phases. A special role in this context is taken in by the production phase. For some products the production of the whole product generation is carried out in one go, for other products – the production is carried out always when a product is ordered.

Subsuming, looking at only one product instance (e.g. Product I-1-A) the singular phases are run through almost completely in sequence, whereas looking at a complete product generation, different lifecycle phases are run through in parallel. This means for lifecycle-oriented planning on the one hand, that for a certain time horizon, requirements and potentials from different parallel running lifecycle phases have to be considered for one product generation (e.g. at Product generation ProG I-1 see long arrow consisting of Production, Utilization and Recycling). On the other hand, for one product generation the planning window may be very large which widens the planning scope and thus leads to more relevant information to be considered in early product planning phases.

Another important perspective addresses the topic of face-lifts of products. Thereby, face-lifts describe the modernization of products within one superordinate product generation (e.g. within product generation ProG I). Before the face-lifted product is produced and sold, the face-lifted parts have to developed (D_F) and embedded within the originally product generation. Thereby, the development phase of the face-lift is often shorter than the development phase (D) at the beginning of the whole product generation. Still, it has to be considered in planning future products in order to define the respective adapted parts in time. One relevant consideration is also the time gap between the first launched product of the overall product generation and the first launched face-lifted product (Δt between start of Product I-1-A and Product I-2-A). Thereby, in some cases face-lifts are already planned for a certain point of time, in other cases the face-lift is triggered as soon as the sales figures of the originally manufactured product decrease. Thus, as face-lifts often intend to lengthen the economic lifecycle of a product, the time horizon to take aspects from the various lifecycle phases is even more extended. As an intermediate conclusion, looking at the discussed temporal aspects increases the transparency in lifecycle-oriented planning, as it becomes clear that for anticipating information of future products, multiple time horizons have to be considered for the whole product generation but also for singular phases within the lifecycle.

2.1.2. Temporal aspects concerning lifecycles of multiple product generations

Similar to the above mentioned topic of face-lifts, the planning department should be aware of multiple product generations when setting up and adapting the product roadmap. In particular the time gap between the first launched product of the first generation and the first launched product of the following generation is of interest (Δt between Product I-1-A and Product II-1-A). Sometimes, this time gap is driven by external factors, such as the frequency of recurring trade fairs. Still, the company has to react — respectively act — on the market by launching new products besides such periodic events. For example, if certain technologies become obsolete by legislative regulations (see Sec. 3), the time period between two product generations can be influenced.

Further, the development of the following product generation has to be started at the right point of time. In order to allow a smooth change between two product generations, the phases of development and production of the following product generation may overlap with different lifecycle phases from the first generation. By considering subsequently following product generations, the time horizon for planning the respective lifecycles again expands. Thereby, the question arises how far it is reasonable to anticipate future product characteristics or respectively the context of future products.

3. TEMPORAL BEHAVIOR OF CONTEXT FACTORS INFLUENCING FUTURE PSS

The mentioned model of context factors [7] helps to identify planning relevant factors. These factors show temporal behavior themselves. Understanding the temporal patterns behind these factors supports the anticipation of information relevant for future products and corresponding services. Factors, relevant for the context of future automobiles, have exemplarily been analyzed in order to determine characteristic patterns. E.g. concerning the planning of power trains, the question arises how resources to operate the car evolve. As most cars are still based on gasoline, the availability of oil can be seen as an important context factor. Thereby, as quite characteristic for raw materials, different long-term as well as seasonal and short-term undulations can be observed.

Concerning the market for electro-mobility, market relevant context factors can be seen in the shift from Micro-Hybrids to Full-Hybrids and Plug-in-Hybrids, where both the absolute number and the numerical proportion between different sold hybrid alternatives will change. Detecting such general patterns within the market might thereby be of importance when planning the future product portfolio. In the technological context of electro-mobility, of course the maturity and availability of batteries can be seen as another essential factor for planning future products.

Another important field within the model of context factors addresses the legislative changes. For automotive industry, for example the CO_2-emission regimentation of cars is an important planning criterion. E.g. looking at the allowed emissions from 1970 onwards one can easily see that a decreasing, stepwise pattern can be detected. The presented examples from different fields of the context model show, that knowledge about respective patterns supports the understanding which products with which properties at which time have to be launched. Being aware of such patterns allows preventing from surprises by extrapolating current trends — at least to a certain extent.

4. TEMPORAL ASPECTS CONSIDERING THE PLANNING RHYTHM

Based on 13 interviews in various branches, the short-, medium- and long-term-planning horizons were reflected upon in industrial practice. The goal was to gain qualitative insights into planning procedures in different industrial sectors. One finding addresses the frequency of long-term planning of future products. Many of the interviewees — holding a strategic planning or respectively a position participating in the planning process — stated that they perform long-term planning with a time horizon of around 15–20 years. They stated that such a long-term planning — mostly using scenario management — should be performed every 3 to 4 years, still making plausibility checks in-between. Based on the interviewees' statements, it is deduced that this planning frequency is rather based on an assumption, as the respective companies only performed the long-term planning once up to now within their company due to the high effort.

Further, the interviews stated, that the companies perform regularly both short- and medium-term-planning, focusing more on the products themselves than on 'fields of action'. Thereby, people from 'research and development' as well as from strategic management come together and discuss the future product roadmap. One of the interviewees stated, that this roadmap addresses projects and according products with start of development within the next three years. Still, a short time after the annual meeting, plans are often changed according to new available information.

As a conclusion from various interviews, many companies are just at the starting point to implement planning procedures towards short-, medium- and long-term planning. Thereby, the need for respective planning approaches to handle information describing future products and corresponding services can be deduced.

5. CONCLUSIONS AND FURTHER WORK

In this paper multiple facets of temporal aspects concerning lifecycle-oriented planning of future PSS have been discussed. Different existing models concerning in particular the lifecycle of PSS as well as the context of future PSS — elaborated against the background of 'managing cycles in innovation processes' — have been presented to describe the fundament of further discussions. Within the discussions, three highly interlinked topics have been addressed. First, the need and benefit of understanding temporal patterns by analyzing lifecycle constellations of single and multiple product generations has been pointed out. Although, the used lifecycle models in this context were chosen at a very high level of abstraction, the general mechanisms can also be transferred to the presented detailed PSS lifecycle model. Another focus was directed on the context future lifecycles are embedded in. Based on the presented model of context factors, it was briefly described how temporal behavior of context factors can be described systematically. As not all context factors show the ability of being extrapolated, the approach in looking at patterns of context factors is limited. Nevertheless, describing temporal patterns of context factors systematically supports the systems understanding in early PSS planning and thus also helps to coordinate the above mentioned temporal lifecycle patterns. Finally, patterns concerning the PSS planning process have been briefly discussed based on first results of a currently ongoing interview series. As discussed, this topic is again highly interlinked with the temporal lifecycle and context patterns. The findings show a qualitative character, as the number of interviews is limited. Still, as the interviews have been carried out in different branches and show similar characteristics, a trend towards an transferability to further branches is given. Currently, discussions focus on lifecycles of complete systems. Further work should therefore address constellations considering different lifecycle of singular product elements in depth, as these may vary very strongly within a product. This is in particular of interest, if service, mechanic and electronic parts of a PSS are more precisely differentiated. To increase an integrated systems understanding even more, current discussions will be expanded concerning multiple products offered by a company.

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