Joint Framework for Product Service Systems and Life Cycle Management

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Abstract

The introduction of Product Service Systems (PSS) fosters the shift from the traditional focus on the sale of products towards the offer of a function of product-service-combinations to customers. The development and management of PSS is an interdisciplinary task and various aspects have to be taken into account. To avoid local optimisation and problem-shifting, Life Cycle (LC) thinking is required in the context of PSS. Existing approaches for Service Life Cycle (SLC) aim at the development and management of services and distinguish LC phases such as idea management, development, production and displacement. Approaches for Life Cycle Management (LCM) generally apply LC thinking to products. As a result, SLC- and LCM-approaches are not well connected with each other and synergies for PSS are often not obvious. Against this background, this paper proposes a concept how service can be integrated into an existing framework for so-called Total LCM. The framework is demonstrated based on the example of mobility concepts.

Keywords

Total Life Cycle Management, PSS, Service Life Cycle

1 INTRODUCTION

Production companies are confronted with an increasing demand to offer (industrial) Product Service Systems (PSS), to cope with the decreasing relevance of secondary market sectors and an increasing influence of the service market [1]. As PSS in general and industrial PSS in special consider a socio-technical system, solutions for PSS need to cope with increasing complexity and interdisciplinary issues. These challenges are addressed by various scientific disciplines like engineering technology, information technology, economics or psychology [2] [3].

The complexity of PSS results in a variety of challenges and production companies need to adopt themselves from product orientation to PSS orientation. Thus, the active adaptation in terms of changes in organisational structures, activities, and behaviours is a challenging task for the management of production companies [4] [5]. To cope with these challenges, a framework is required to structure the life cycle of PSS, classify and depict the mode of action of concepts, methods and tools and to help acting persons to understand engineering and management functions [5]. For that, the Total Life Cycle Management (TLCM) approach provides a framework for production companies that fulfil these requirements. To support companies offering services or PSS, an enhancement of the TLCM framework is required that integrates the specific characteristics of services.

2 PRODUCT RELATED LIFE CYCLE MANAGEMENT

Executive managers of companies face a highly complex and turbulent environment with social, political, economic, technical and ecological interdependencies. They need to cope with life cycle phases of products and services with respect to a sustainable development as well as to the internationalisation of markets, the development towards an information society and the change of values of employees and customers. Within this context, Life Cycle Management (LCM) frameworks have been developed in order to link different disciplines, to uncover interdependencies and to promote the integration of disciplines and methods [4] [5].

2.1 Requirements on Total Life Cycle Managements

The framework of TLCM is meant as a holistic LCM framework that aims at supporting management towards a sustainable development. It therefore has to meet requirements that can be summarised as follows:

- It generates transparency by structuring management activities with regard to product life cycle phases.

- It supports the understanding of general correlations between management disciplines of a life cycle management on the one hand as well as structures, activities and behaviour of involved actors on the other hand.

- It integrates various disciplines into a holistic approach with the following characteristics:
  o Life cycle spanning perception on products and processes
  o Integration of the statement for a sustainable development as part of the management philosophy with its ecological, economic and social goal dimension
  o Integrative consideration of strategic, operational and normative management
  o Consideration of attitudes, convictions and values of involved actors
  o Interdisciplinary consideration of different actors within the value chain

- It provides the opportunity for linking the life cycle of a primary product with used secondary products.

It facilitates the classification of existing and new management concepts, methods and tools.

2.2 Framework for Total Life Cycle Management

The framework is based on the ideas of the Viable System Model [6] and the St. Galler 'concept of integrated management' [7] [8]. The TLCM is a systemic and life

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cycle oriented framework for a life cycle phase comprehending point of view on products and the corresponding processes [9] [4] (Figure 1).

Figure 1: Framework of Total Life Cycle Management [4].

The centre of the framework is formed by the life cycle phases of a product – from *product idea* to *disposal*. Start of the entrepreneurial acting is the statement of a sustainable development as a super-ordinate philosophy. It is part of the normative management level that can be distinguished from the strategic and operational management levels. Thereby, the normative and strategic management have a rather forming function with regard to the development of the company [10]. Furthermore, the fields of action are classified into structures, activities and behaviour. Activities in the individual product life cycle phases lead to the output of the company. The activities take place according to the organisational structures and the behaviour of management and employees. These fields of action are part of all sectors of the concentric management rings.

In addition to management fields of action, the TLCM framework is divided into different LCM disciplines. These are classified in *life cycle spanning disciplines* (process management, information- and knowledge management, social life cycle evaluation, economic life cycle evaluation, ecological life cycle evaluation) and *life cycle phase related disciplines* (product management, production management, after-sales management, end-of-life management). The disciplines aim at a life cycle oriented design of products and processes and are based on the organization structures and the behaviour of involved actors.

As the term 'total' in TLCM refers to the holistic view on all company activities with respect to sustainability and life cycle orientation, the framework should be applicable for all types of companies and all types of products including products as well as services. Due to specific characteristics of services, the applicability of TLCM needs to be enhanced. As the main focus of TLCM was on products, service characteristics have not been considered in an adequate manner. Thus, the framework for TLCM will be enhanced for services in the first step and for PSS in the second step.

3   LIFE CYCLE MANAGEMENT FOR SERVICES

The relevance of the service sector, also called tertiary sector, has increased significantly in industrial countries during the last century. Today, in many industries, services are the most important business sector amounting to more than 70% of the national economy. Thereby, services are specified on the basis of an enumerative definition [11]. However, no distinct definition of the term "service" has been established in the scientific literature [12] [13].

3.1   Service characteristics

With reference to scientific literature, constitutive approaches provide the most distinct definition of services. These are defined on the basis of service-specific characteristics to determine the main core of services. Thereby, services are defined as independent, competitive performances that are connected with the preparation and/or the use of capabilities (potential orientation). Internal and external factors are combined within the process of provisioning services (process orientation). The combination of factors of the service provider is applied with the aim to achieve useful effects for the external factors such as people or objects (result orientation) [14] [2] [15].

Referring to this definition, it can be distinguished between a potential-, process-, and result-oriented dimension of services. This differentiation is widely accepted in literature and can be ascribed to [16] [17]. In addition to this, a fourth dimension, the market dimension, becomes consent and is found in literature as well. Thereby, the profitability of services from economic point of view is an essential characteristic and can be achieved by customer orientation within potential-, process- and result-oriented dimension [18].

Beside these four service dimensions five service characteristics have been identified [19]. These are suitable for defining services on the basis of constitutive characteristics (figure 2).
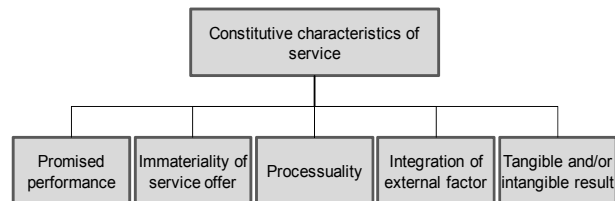

Figure 2: Constitutive characteristics of services [19]

- *Promised performance:* This characteristic applies to the willingness to perform and the potential needed to provide a service (e.g. buildings, technical equipment or employee and employer skills). In this context, the description of services takes place on the basis of the potential dimension.

- *Immateriality*: The immateriality view on services focuses on the promised performance offered on the market by the service provider. Based on this understanding, services are regarded as intangible. Therefore, the constitutive characteristics immateriality and offer of a promised performance are directly associated.

- *Process orientation*: Services are based upon an interaction process between a service provider and a service consumer. Thus, this service characteristic focuses on the process dimension of services.

- *External factor*: Due to the interaction process of services, the integration of an external factor, i.e. people, objects, or information is necessary. This results in the uno-actu-principle, meaning the simultaneous production and sale of services. The integration of external factors also refers to the process dimension of services.

- *Tangible or intangible result*: This characteristic refers to the outcome of the service provision process. In contrary to a product, the result can be tangible as well as intangible and has to meet the demands and

perceived benefits of the customer. Therefore, the centre of interest is the change of the condition of the service consumer or his objects.

3.2 Service Life Cycle

Besides the consideration of service characteristics, the specification of the Service Life Cycle (SLC) is also necessary in order to enhance the existing framework for TLCM with respect to services.

For the description of SLC different approaches have been developed. They intend to describe the single phases of services. The objective of SLC approaches is to illustrate the service life cycle in terms of sequent phases in which the interaction of required methods and tools is coordinated.

Existing SLC approaches vary in their description as they define different phases in the life cycle and use different terms for the phases [15]. Generally, they are based upon a development-oriented view, e.g. the "procedure model for systematic service development" from [18]. These approaches are characterised by defining SLC phases with a focal point on the time period previous to the service production and utilisation. Another group of existing approaches consider life cycle phases of "service production" and "usage" as well as phases subsequent to the usage. Examples are the "Bio-Inspired Service-Life-Cycle" [20], the "Service Design and Management Model" [21], and the "Phase Model for Service development" [22].

Although existing SLC approaches are mostly based upon the specific characteristics of services, they do neither include a management perspective nor integrate various disciplines into a holistic approach as described in chapter 2. In addition to this, most SLC approaches neglect single service characteristics as described in chapter 3.1. Except the approach developed by Bullinger [18], other approaches do not consider the characteristics of promised performance for service development. Moreover, the majority of existing approaches do not integrate the provision of potential factors needed for the service performance within the service life cycle phases. In conclusion, it can be stated that existing SLC approaches are not suitable for being used as a basis for a framework for Service LCM.

3.3 Service-related LCM

If service shall be described within a framework for Service LCM, service-specific characteristics and life cycle phases need to be considered simultaneously within the context of life cycle management. Thus, a framework for Service LCM has been developed within the TLCM approach with regard to existing SLC approaches. It is illustrated in figure 3 and will be described from inside to outside.

Life cycle phases

The centre of the framework illustrates the service life cycle phases – from *service idea* to *recycling*. Thereby, the traditional life cycle phases from TLCM have been consolidated with those taken from existing SLC approaches [22], [21] and [18].

Starting point for all services is a *service idea* that is detailed and designed within the *service development* phase. Service specific characteristics explicitly have to be considered, as the *provision of potentiality*, i.e. required resources, is part of the SLC. Furthermore, the immateriality is respected by integrating the *service production and service usage* as one isochronous phase. Thereby, its disjunction into two parts reflects the integration of the external factor. One part represents the service provider's processes; the other process part refers to the external factor that needs to be integrated. Finally, the *recycling* phase of SLC considers the need for utilisation and recycling of the provided potential factors as well as the possibly required adaptation of provided services with respect to new customer requirements.

Management perspective

As Service LCM integrates a management perspective into the depicted framework, it distinguishes between a *normative*, *strategic* and *operational management* level as well as *structures, activities* and *behaviour* as fields of action. Again, the management fields of action have to be considered in all sectors of the concentric arranged management levels. The strategic management has a rather forming function with regard to the development of the company, here the service company. An important difference between the framework for Service LCM and the existing TLCM framework is the integration of the external factor, depicted as the customer in figure 3. A private or industrial customer, has its own normative, strategic and operational management understanding as well as own structures, activities and behaviours. Structures, activities and behaviours of the service provider and of the customer need to match to each
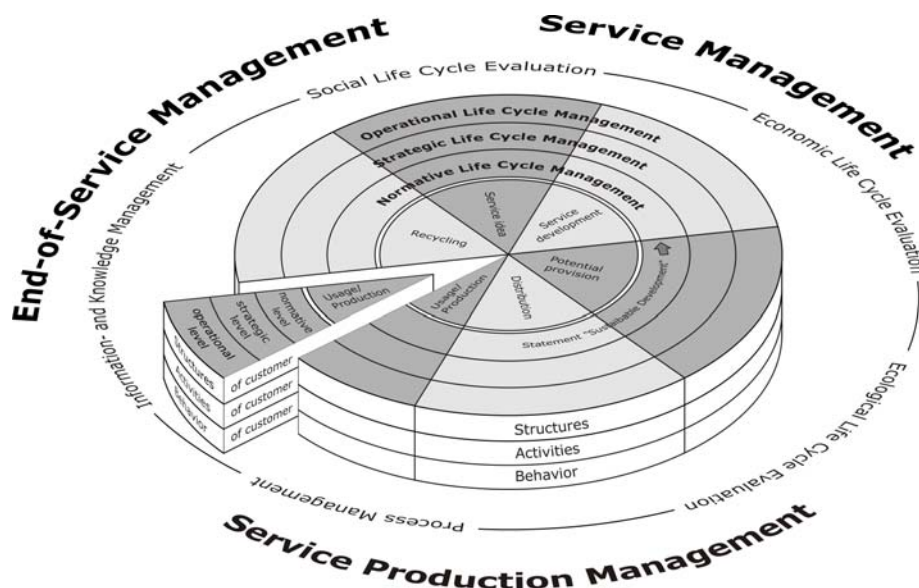

Figure 3: Framework for Service LCM

another in order to efficiently organise the phase of service production and usage. For instance, if a specific production process of a car manufacturer (e.g. assembling) has been outsourced to a service provider, the operational management within the production phase of vehicles (see figure 1) needs to be aligned with respect to the operational management of the service production phase of a service provider (figure 3).

Life cycle disciplines

According to TLCM, the framework for Service LCM is divided into *life cycle spanning disciplines* and *life cycle phase related disciplines*.

Within the *Service Management*, the service life cycle strategy and design need to be considered in all four service dimensions, i.e. the product, process, potentiality and market dimension. Thereby, the market dimension aims at developing a service that is compatible to the management levels of the customer (operational, strategic and normative).

The *Service Production Management* refers to the management of required resources for offering a service on the one hand. On the other hand it implies the management of providing services itself. This contains e.g. management guidelines for employees and their behaviour as well as service process descriptions within the operational life cycle management. In addition to this, an explicit consideration of the customer within the production and usage phase is required. Thus, the task for harmonising the management fields of action of the service provider and the customer is also part of the production management.

Finally, the *End-of-Service-Management* implies the planning and controlling of all activities at the end of service life. This contains the utilisation and reuse of service elements for new service ideas as well as the recycling of material results of the services.

As the framework for Service LCM is derived from the TLCM framework, a management perspective is explicitly included. Furthermore, it integrates the various disciplines into a holistic approach as described in chapter 2. Starting with the statement of a sustainable development it deepens the understanding of the general correlations between management disciplines and structures, activities and behaviour of involved actors within Service LCM. Thereby, service characteristics are explicitly regarded.

4   PRODUCT-SERVICE SYSTEM (PSS)

In contrast to the traditional philosophy of manufacturing and with the focus on manufacturing and selling products, the PSS-approach requires a shift towards offering a (specific) function to the customer. This requires the provision of a whole range of product and service combinations. Thus, the described framework for Service LCM should be part of TLCM and result in an integrated framework for PSS LCM.

4.1   PSS characteristics

A PSS is a bundle of products, services, networks of actors and the supporting infrastructure with the aim to be competitive by satisfying the customers' needs and at the same time to have a lower environmental impact than traditional business models [23]. Product and service are equally important for the function fulfilment [24] but the relation between services and products [25] and consequently the characteristics of PSS varies.

As the PSS concept shifts the relationship between manufacturer and customer, new business models with changing ownership structures emerged [26]:

Product-oriented business models provide additional services to sold products (e.g. financing, consultation),

- Use-oriented business model focus on the use of products that are sold, not the product itself (e.g. product renting and leasing),

- Result-oriented business model focus on a provider that guarantees satisfaction of customer needs, regardless of disposed products (e.g. facility management, mobility).

For the management of PSS the integrated and life cycle-oriented management of a product in combination with a service is necessary. Characteristics of services need to be regarded as well as characteristics of products.

Because services have only been integrated into the framework for TLCM in terms of a product-oriented business model (i.e. After-Sales-Management), it is not suitable for being used for PSS. A framework for PSS LCM needs to be an integration and combination of Service LCM (cf. chapter 3.3) and the TLCM framework (cf. chapter 2).

4.2   PSS Life Cycle Management

Within a PSS neither the product nor the service is solely important, but the required function of the total system as a result of the product and service combination. As to this, suitable PSS LCM approaches are necessary for the management of this multi-disciplinary, socio-technical system. As PSS is a new field of research, holistic approaches for the integration of a product view and a service view do rarely exist [27]. By integrating the framework for TLCM and Service LCM into one consistent framework for PSS LCM this drawback shall be addressed. Thereby, the integration of life cycles as well as the continuative management disciplines of TLCM and Service LCM can be implemented in diverse depths.

The first integration step is presented in figure 4. The Service LCM and the TLCM are connected in the usage phase of the product and the usage and production phase of the service. Thereby, TLCM and Service LCM are still represented separately, but interdependences are considered.
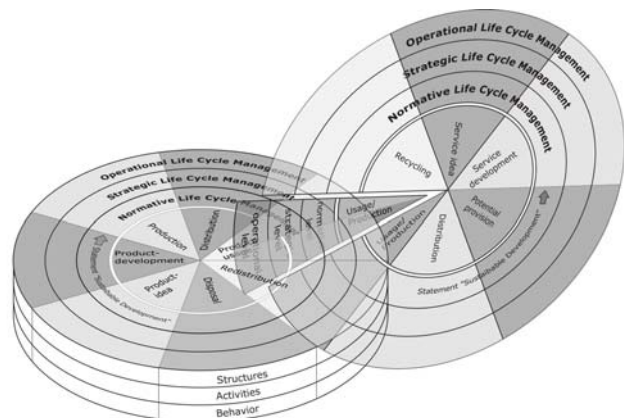

Figure 4: Connected framework of TLCM and Service LSM

In various life cycle phases an exchange and coordination between the life cycles of offered services and related products are needed. Between the levels of management, there has to be a link as well. The levels act independently but in close coordination. With this first integration step PSS requirements coming from its definition are only partly achieved. Thus, a product-related service is rather shown here, which frequently occurs in the economy.

Within an overall framework for PSS LCM, the management of services and products is combined in a unit that deals with the required function and regards the needs of the embedded services and products as equally important. To achieve this, an integration and connection of the life cycles of services and products to a common life cycle is needed. The management levels must rely on an integrated management for the common life cycle. For better understanding a mobility concept of car-sharing is used as an example (see figure 5). It meets the definition of a PSS. With this example, a mobility concept allocates the function mobility to the customer. This function is realised with an integrative combination of a mobility-enabling product (e.g. car) and a mobility-providing service [28].
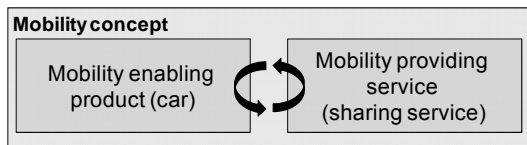

Mobility concept		
Mobility enabling product (car)	⟳	Mobility providing service (sharing service)

Figure 5: Mobility concept for car sharing [28]

Using the example figure 6 represents the integrated PSS LCM framework for a mobility concept.

Life cycle phases

The PSS life cycle is in the centre of the framework and starts with the *PSS idea* for the joint PSS (e.g. the idea for a car-sharing offer). The *PSS development* implies the integrated development of product parts and service parts. Within the context of car-sharing this corresponds to the development of a car as well as the services that enable the process of sharing (business processes, workflows, rules etc.). A particular attention is needed for the development of the interfaces between the car and the service.

The *PSS development* phase is followed by the *production* of the product component (car) and the parallel *provision of the required potential* for the service part of the PSS (e.g. a booking system, entry requirements, specific parking space, employer's skills, etc.). Here, a division into the life cycles of the product and the corresponding service takes place. This division is ascribed to the different characterisation of services and products. While the product needs to be manufactured before using, the immateriality of services is linked to the subsequent usage and production phase and the potential provision phase.

Within the *distribution* phase the PSS is marketed and the product as well as the physical portion of the available potential is prepared. Following the example of car sharing, the developed car sharing concept is offered to the customers, the car is shipped to its basic position and contracts and entry requirements are sent to the customers.

In the next phase, the *usage* of product and services takes place, simultaneous to the *production of services* to the customer. As described with the Service LCM in chapter 3.3 the customer and the customer's processes need to be a part of the service provision and use, in figure 6 illustrated by the separate representation of the customer in the phase of usage and production. E.g. the customer books a car by using the booking system and starts on the parking space. By starting to drive the car, the function of mobility is achieved. The integration of the external factor is needed even though a product is part of the PSS due to the immateriality of the service part (the mobility).

The last phase of PSS life cycle is *recycling* of the immaterial service and *redistribution and disposal* (or recycling) of the product. This phase considers the need for disposal of the provided potential factors and physical parts as well as the possibly required adaptation of provided services. For the PSS "car sharing", this can be divided into three scenarios.

First scenario: The car is redistributed and disposed, whereas the service or service characteristics are recycled to be used with another product or new car (car generation) starting a new life cycle of another PSS.

Second scenario: The service is suspended. The provided potentials are reduced and, if necessary, recycled. The car needs to be redistributed and can be reused in a different mobility concept (a new PSS).

Third scenario: The car is redistributed, disposed and the service is suspended. The provided potential factors are disposed or reduced.

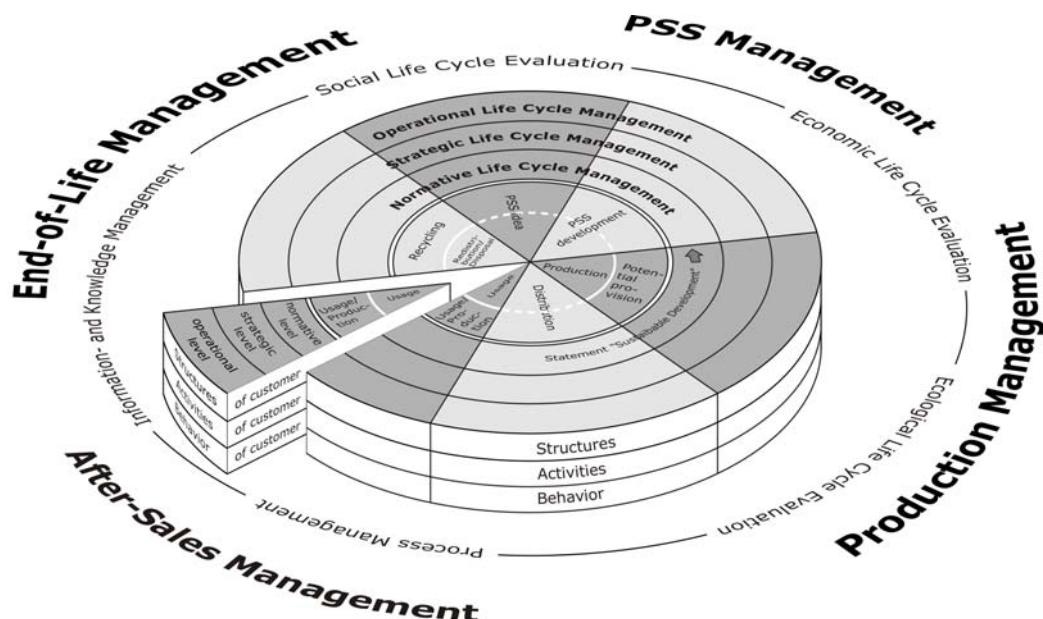The integrated PSS life cycle takes into account the

Figure 6: Framework for PSS Life Cycle Management

service characteristics (according to the depicted life cycle for Service LCM), while the requirements for the life cycle of the product are considered as well. The life cycle can be applied regardless of how distinctive the service part or the product part is in the PSS.

Management perspective

The framework for PSS LCM integrates a management perspective with a *normative*, *strategic* and *operational management* level as well as *structures*, *activities* and *behaviour* as fields of action. The management perspective of PSS LCM refers to the fulfilment of functions of PSS and therefore equally to both parts, service and product parts. Regarding the PSS "car sharing", the management perspective integrates the car as well as the sharing services. In analogy to Service LCM, PSS LCM explicitly considers a customer part. Herewith, the integration of the external factor with its own normative, strategic and operational (management) level as well as own structures, activities and behaviour in the service production and usage is displayed. Within the example, the car sharing customers' structures, activities and behaviours and its valuable mindset, strategies and plans should be taken into account for the providers' management fields of action in order to efficiently go through the phase of PSS production and usage. For example, if a customer target group is characterised by "green attitudes", this has to be addressed by an environmentally friendly car.

Life cycle disciplines

Likewise TLCM and Service LCM, PSS LCM is divided into *life cycle spanning disciplines* and *life cycle phase related disciplines*. Life cycle spanning disciplines are invariant to the regarded product (product, service or PSS) and differ only in terms of the system boundaries. Life cycle phase related disciplines however adapt to the PSS.

The *PSS Management* aims at the development of a PSS idea and the design that considers the PSS as a function fulfilment of equal parts of a product and service. Thereby, properties of products need to be regarded as well as all four service dimensions.

Within the *PSS Production Management*, processes for service and product production are simultaneously regarded. This implies the required production of resources and potentials for the service production as well as the management of product production. Furthermore, the harmonisation of the management fields of action of the PSS-customer and PSS-provider becomes a central element of the PSS Production Management. The life cycle phases product production and potential provision as well as product usage and service production/ usage are connected within this life cycle phase related discipline.

In the *After-Sales Management* the usage of the product and its related processes are regarded. However, this discipline focuses more on the harmonisation of after sales activities of the physical part and the usage and production of the service part of the PSS so that the promised performance can be fulfilled.

Finally, the *End-of-Life Management* comprises the processes and activities at the end of the PSS life. This contains structures, activities, and behaviours that are required for the redistribution and disposal of physical components as well as the adaptation or removal of services and acquired resources.

5   CONCLUSION

The framework for PSS LCM is an integration of the existing TLCM framework and a Service LCM framework. It generates transparency by structuring management activities with regard to PSS life cycle phases. It integrates various disciplines into a holistic approach and therefore fosters the understanding of correlations between management disciplines and structures, activities and behaviour of involved actors, i.e. the regarded company and the customer. Service and product related characteristics are simultaneously regarded and a common life cycle for PSS is integrated.

The framework for PSS LCM complies with the requirements for a Life Cycle Management framework as well as the requirements coming from the definition of PSS. Irrespective to the ratio of product part and service part in the PSS, the management of the PSS can be described with this framework.

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