Chapter 1

PSS Layer Method – Application to Microenergy Systems

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Abstract Within this chapter three main topics are wrapped. First, a relatively new method for the development of Product-Service Systems (PSS) called PSS Layer Method is introduced. Second, microenergy systems are introduced as a commendable example to teach the theory of Product-Service Systems. Third, sustainability as a driver for Product-Service Systems and microenergy systems will be emphasized. All three topics are set in relation to an industrial case where the PSS layer method had been applied to a microenergy system which in this case is a solar home system. Such systems are used for energy supply in off-grid installations in rural regions, e.g., in weak infrastructures of developing countries. The reader will learn the basics of the PSS layer method, be introduced to microenergy systems and get an insight on a discussion on sustainability concerns in this case. The chapter closes with reflections on experiences, recommendations for an industrial application of the PSS layer method and an outlook.

Keywords Development of Product-Service Systems, Modelling of PSS Ideas and Concepts, Sustainability

1.1 Industrial Challenges

In a company implementing new mindsets, imparting new development methodologies, teaching developers in consistent method application and rolling out related business processes is tough business. Especially if more than one domain is involved and when each domain has its own particular approaches which are not directly compatible with others. As approaches for Product-Service System (PSS) development, viz. approaches for product-service integration, are relatively new to industry, those challenges will also become evident in this topic.

Furthermore, creative work in groups with members of different competencies in product development, marketing, management or business development lacks under differing terminologies and foci. Particularly in PSS development, a mixture of such competencies in early development phases is inevitable to generate innovative solutions. The design of a sustainable business model is type of a strategic task, whereas the design of the technical solution or enabler (core products, service resources and activities, deliverables, etc.) is type of an engineering task. Nevertheless, the business model and the technical solution have to complement and support each other appropriately to efficiently satisfy customer needs and sustainability requirements.

The PSS layer method is one of our approaches to facing such challenges. Briefly said, it integrates the views of customers, engineers and economists, it defines a common "language" and a simple, graphic modelling scheme. It is supposed to be applied mainly in early development phases to analyse and synthesize ideas and concepts of PSSs. It helps to generate requirements, to become aware of PSS functions and to derive tasks for further development.

1.2 From Product-Service Systems to Sustainable Microenergy Systems

1.2.1 Introduction to Product-Service Systems

Product-Service Systems (PSSs) is a concept that integrates products and services in one scope for planning, development and delivery, thus for the whole life-cycle. It is predominantly used in academia but widely unknown by industry. Nevertheless, solutions integrating products and services are attracting attention. Some providers consider themselves as solution providers who essentially offer solutions including products and services. For several years many research projects all over the globe have concentrated on product-service integration. Many terms with nearly equivalent meanings have been introduced into the PSS landscape from engineering, economic or social viewpoints. Close to PSS there are concepts like

“Service Engineering” (Tomiyama 2001, Lindahl *et al.* 2005, Bullinger and Scheer 2006), “Integrated Product Service Engineering” (Integrated Product Service Engineering 2009), “Functional Sales”, “Functional Product Development” (Functional Product Development 2009) or “Industrial Product-Service Systems” (Transregio 29 2009). Furthermore, PSS have been linked tightly to sustainable development or eco-design, (McAloone and Andreasen 2004). As all those concepts are close to each other they are within the scope of this contribution and summarized under the concept of Product-Service Systems.

> The value provided by the concept of product-service systems is a broad, holistic view on technical systems by taking into account actors, technical artefacts, services, business models and drivers like sustainability and dematerialization. Constraining is the premise of providing added value to satisfy customer needs and to meet ecologic, economic and social requirements along the whole life-cycle of a product-service system.

Customer needs are not simply reduced to a single need for product ownership. The basic idea is not to sell products and services separately, but to sell a defined result, a system’s availability or functionality to add value. The integration of products and services finally can maintain or enhance functionality of a product or a service or implement new functions which are not available without integration. To make this approach successful there is a need for long-term commitments within the stakeholder network. Specific business models (see Tukker 2004) are used to reach that aim and bound customers to their providers over long periods. Maintenance, system adoption to changing needs and boundary conditions, reconfiguration or upgrading can be part of a PSS business model. This requires the partial substitutability of products by services and vice versa. By contract, it is defined how risk, responsibilities and costs of an integrated delivery and operation of product and service shares are distributed among the stakeholders, (Steven *et al.* 2008). An important aim is a value co-creation among the stakeholders during the integrated delivery process. Supplemental systems and tools have to be taken into account to enable the delivery of products and services and the exchange of information. Fig. 1.1 illustrates in a simplified, minimal architecture the PSS core elements.

1.2.2 Introduction to Microenergy Systems as an Example of PSS

Microenergy systems have an interesting combination of strongly interlinked technical, economic, ecologic and social aspects, and thus they are a convenient PSS example. A microenergy system is a small decentralized energy conversion unit that meets the energy demand of households and small enterprises. Microenergy systems play a crucial role in regions with poor infrastructure and low incomes in developing countries where households and small enterprises often have insufficient access to modern energy services. These regions are denominated “Microenergy Sector” (Philipp and Kebir 2004). According to the World Bank, more than 1.6billion people lack access to electricity and 2.4billion rely on traditional biomass for cooking and heating (World Bank 2004).

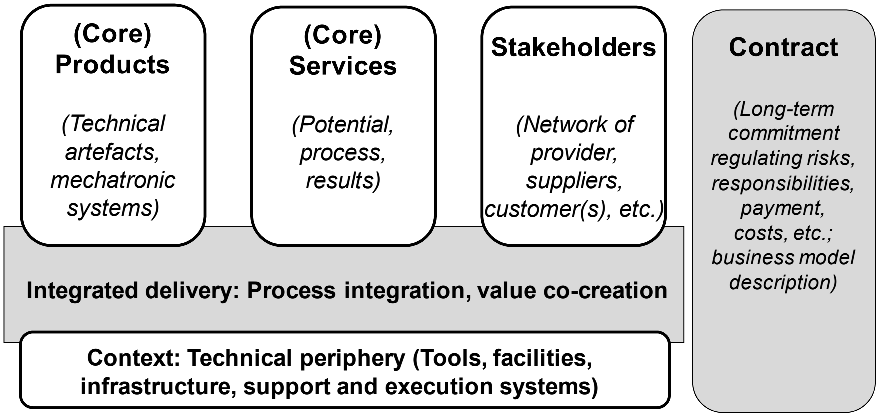

Fig. 1.1 Core elements of a product-service system (Müller and Stark 2008)

Several field and market studies have shown that a rise in trading with appliances using and converting energy takes place in the microenergy sector; in particular the demand for TVs, radios, kerosene cookers and petroleum lamps is tremendous. Diesel generators help to actuate pumps and supply small decentralized grids with electricity. With the help of accumulators, especially car batteries, electrical power is stored and transported to regions which are situated many miles away from the electricity source or the generator (Hammond *et al.* 2007, Schneider 2003). Fig. 1.2 shows a typical example of batteries and lamps used in rural households. Fig. 1.3 gives insight into a battery shop.

SME and households are facing increasing energy costs. In certain regions, they can reach up to half of the monetary monthly income. The usual inefficient microenergy systems can reach costs up to 1.50 € per kWh (compared to an average of 0.20 € per kWh in a European context), and thus offer a great economic substitution potential for modern energy systems which are more efficient and can be run with renewable energy (Schneider 2003, Philipp and Kebir 2004). Thus, running costs for fuel can be decreased or eradicated completely. The result is recourse savings, higher productivity and a range of indirect economic impacts on health and education of the users. Furthermore, quality of life increasingly becomes tangible. All these results and impacts will be discussed later in detail.

In most cases, efficient microenergy systems have higher investment costs than common technologies and therefore often require financing options, e.g., based on micro credits. The savings customers make on running costs and the additional income they earn due to higher productivity can both be used to refinance the loan. Furthermore, there is a need for services accompanying installation, maintenance, etc. Businesses with microenergy systems require such services to become efficient, those systems can be considered as product-service systems.

Fig. 1.2 Example of a battery and petroleum lamp in a rural household

Fig. 1.3 Example of battery types offered in a battery shop

The example discussed in this chapter is a solar home system (SHS)–an efficient microenergy system that is based on photovoltaic technogoly: a technology that converts solar energy into electricity. The photovoltaic cell panels are fixed on the roof of a customer's house. During sunshine, they load an accumulator. The stored energy is used to run lights and several small electrical applications like TVs and radios. Fig. 1.4 shows an example of the installation of a solar panel which belongs to a solar home system. Fig. 1.5 shows a typical situation where components of a solar home system are being transported on a bike.

Fig. 1.4 Example of the installation of a solar panel on a roof

Fig. 1.5 Typical situation where components of a solar home system are transported on a bike

1.2.3 Introduction to Sustainability

Although PSS has a historical background in eco-design (McAloone and Andreasen 2004) a PSS is not automatically sustainable; but, as it will be shown in the following example, the PSS approach can be very helpful to describe and design a system with requirements toward sustainability (Tukker 2004).

According to the 1987 report of the World Commission on Environment and Development to the United Nations Assembly, sustainability is defined as development which meets the needs of today's generation without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987). In order to develop sustainable solutions in that sense, three dimensions have to be taken into account and also be aligned (e.g., Deutscher Bundestag 1998, Finkbeiner 2007):

- The *ecologic dimension* includes the protection of natural resources such as climate, soil, water and air, but also the diversity of species and ecosystems. The ecological sustainability of products and processes depends on their emissions and resource consumption during the entire life-cycle.
- The *economic dimension* means to evaluate the increase of the economy and the long term welfare, security and prosperity of the society. An essential objective is safeguarding the market functions as, for example, competitiveness.
- The *social dimension* requires the evaluation of lifestyles to leave future generations opportunities to satisfy their own needs and the fairness of distribution systems.

For this purpose, it is crucial to evaluate PSS by these three dimensions. Nevertheless, the three dimensions are not directly applicable as design dimensions for products, services or processes as system properties and characteristics are not directly expressed by them. Designers concentrate on system characteristics and properties such as power consumption in standby mode or frequency of battery exchange which can be more or less sustainable depending on a use process and on the comparison scale. Finally, these three dimensions can be applied to an “assessment-for-sustainability” rather than to a “design-for-sustainability”. Thus, in our case, we assess the sustainability of the solar home system investigated by reflecting relevant system properties and characteristics on the three dimensions of sustainability.

1.3 The PSS Layer Method

The theoretical basis of the PSS layer method is explained in this section. In Sect. 1.4, a detailed description is given accompanied by the application case solar home systems of the company MicroEnergy International (MEI) in Tanzania. The application case delivers concise insight into our findings.

1.3.1 Purpose and Use

The PSS layer method is supposed to be applied mainly in early development phases, thus its purpose is supporting the clarification of the design task and the conceptual design phase according to the terminology of Pahl *et al.* (2007), see Fig. 1.10. It is a method to analyse and synthesise PSS ideas and concepts.

The method has a discursive bias; it proceeds stepwise and iteratively, and enables a structured documentation of an existing or a future PSS. It defines a meta-model of nine main element classes for a PSS.

As a result the user gets a structured outline and the "big picture" of his PSS idea or concept. This big picture helps to hightlight requirements and tasks for the PSS design.

1.3.2 How it Works

1.3.2.1 Main Classes

As mentioned, nine main classes have been defined. The central class is the *Life-cycle activities* class. Activities performed by a customer and/or provider are mapped horizontally along the timeline on a layer for this class. Activities can be part of the product use or product and service provision. The classes *Needs* and *Values* are used to represent the customer's perspective. The class *Deliverables* summarizes all material and immaterial results (information, products, materials, health improvement, etc.) provided to the customer during an activity. The designer's view, or the particular "technical solution" to satisfy the customer needs, is represented by a whole set of classes, namely *Actors*, *Core products*, *Periphery*, *Contract* and *Finance*. These classes contain basic elements which are related to the life-cycle activities as types of resources and boundary conditions and thus are important to implement the future PSS. Vertically all elements which "belong" to one activity of the life-cycle activities class are interconnected. Finally, activities are kinds of connectors of resources which result in deliverables.

1.3.2.2 Modelling of Class Elements in Layers

All classes are graphically layered to simplify the representation; this is where the method derives its name; see Fig. 1.7. Each layer has to be filled by simple scratches, models or text in order to model single elements of the particular class. The layer scheme can be used as a whiteboard method, paper-based or with computer support.

If a technical artefact is chosen as a starting point, its product context (vertical dimension) is analyzed over life-cycle perspectives (horizontal dimension) in detail. If a customer need is chosen as the starting point, the designer can define new system elements on each layer in order to satisfy that need. System elements which have direct connections are mapped vertically one above the other. Already detected or determined system elements can help to identify other system characteristics which have to be detailed in the form of infrastructure or resources or which have to be ensured in the contract. The layers can be used to elaborate on single phases/episodes of the PSS life-cycle, if not on the whole life-cycle.

In principle, the order of the layers is not important, although the ordering in Fig. 1.7 is recommended. The designer may reorder them or even add new optional layers to bring in new points of interest. For instance, the costs might be a good example. Fig. 1.6, Fig. 1.8 and Fig. 1.9 show filled layers and particular details.

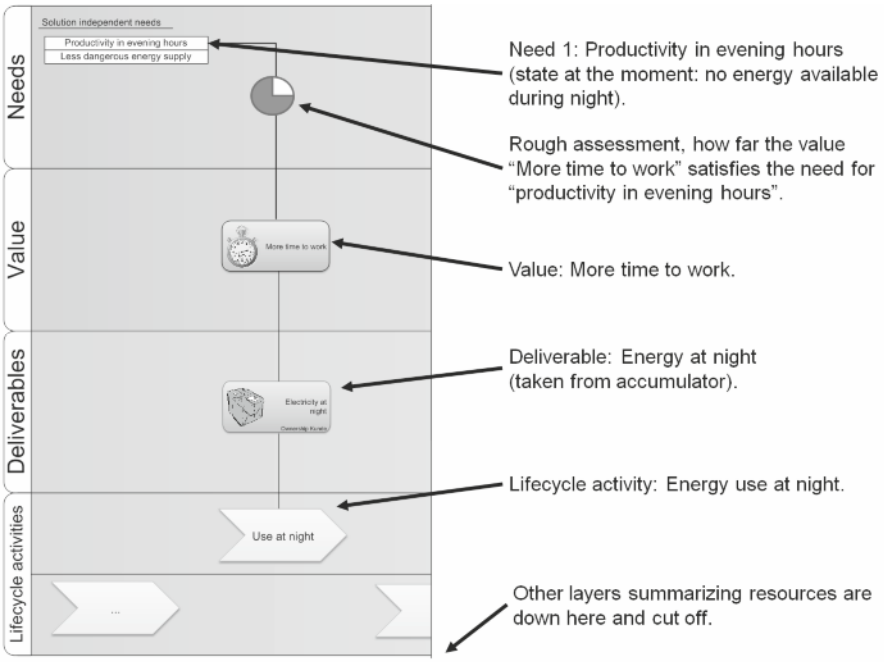

Fig. 1.6 Reduced layer scheme and element number to illustrate how needs and values are used to assess a deliverable. A software toolbox for Microsoft Visio has been implemented to create layer plots with predefined symbol sets for each layer class

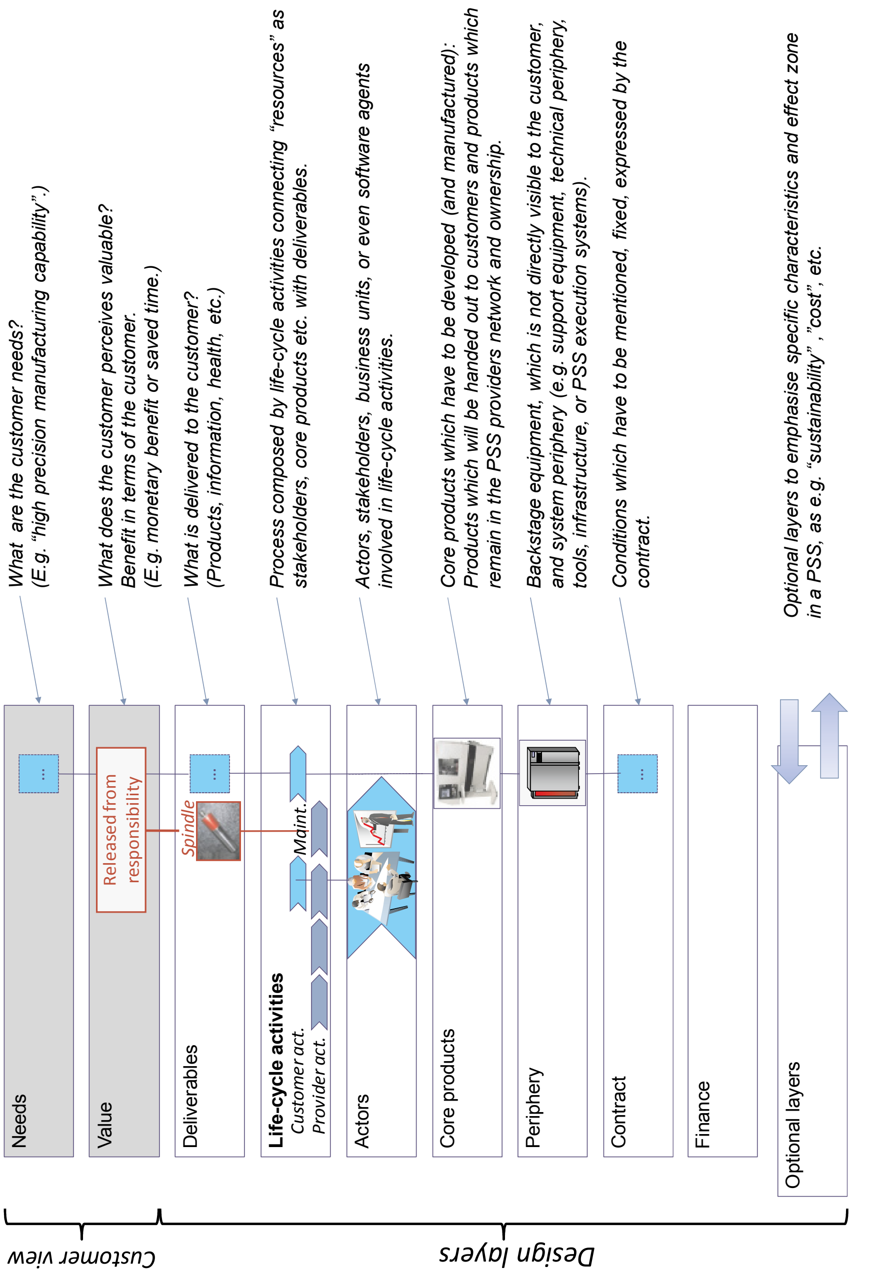

Fig. 1.7 Modelling scheme of the Layer Method. The example indicates elements of a PSS manufacturing system where the provider carries the responsibility for maintaining a rotating spindle; details have been left out.

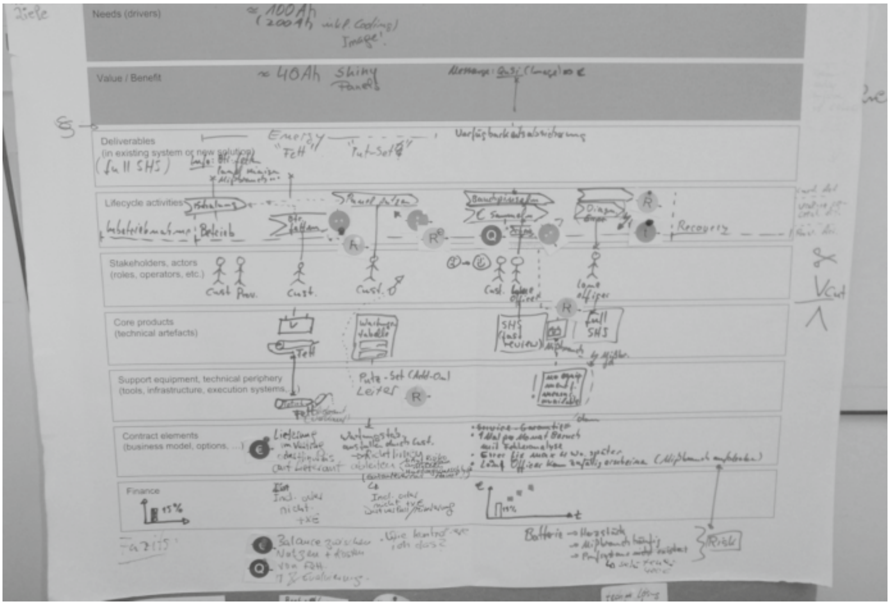

Fig. 1.8 Picture from an earlier layer version used during a workshop on solar home systems. The layer names in this version were changed later. The starting point was the solar panel; needs and values were modelled later. Several of these DIN A1 sheets have been filled

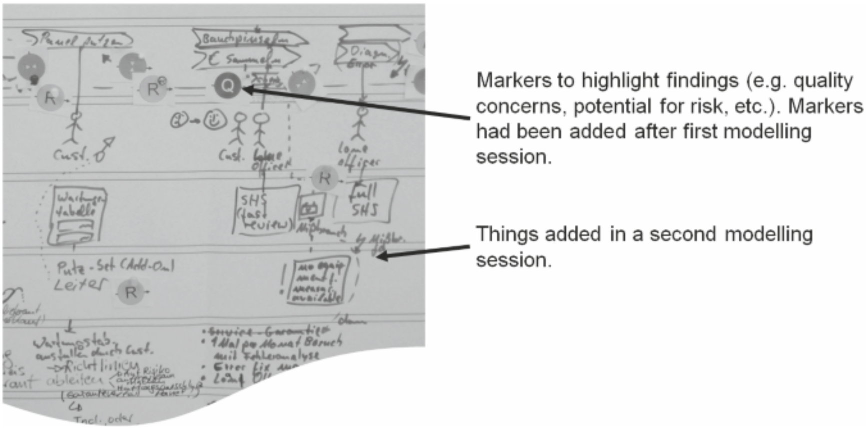

Fig. 1.9 Cut-out of Fig. 1.8 to highlight some details. For each modeling session different colors were used. Between different sessions removable markers were used to highlight findings

1.3.2.3 Remarks on the Representation of Services

The services are not directly modelled. The PSS is interpreted as a process or an activity chain which leads to (added) value.

According to (Bullinger and Scheer 2006 after Hilke) services are built in three dimensions: The result dimension, the process dimension, and the potential dimension. The first dimension defines the outcome of a service which is analogue to the deliverable in this PSS modelling approach. The second dimension has its analogy in the life-cycle activities layer. The third is represented by all other layers in the designer perspective. Even core products, infrastructure or contracts are interpreted as a type of resource and analogue to the potential dimension.

1.3.2.4 Application Process

For an effective use of the method for PSS planning and concept design it is important to have all prerequisites collated. Information on the customer point of view, the market and the company's strategy should be available. This is important to decide whether to design a solution to satisfy customer needs, to evaluate a solution in terms of customer value and, for example, to make robust make-or-buy decisions for product and service development and delivery. Therefore, a phase for the collation of prerequisites is included in Fig. 1.10.

Accompanying the modelling detected requirements, important system functions and new development tasks should be written down for later deployment.

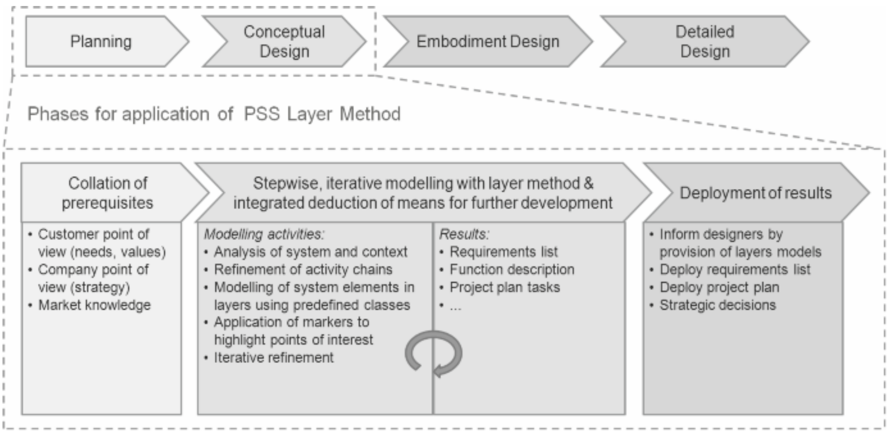

Fig. 1.10 Integration of the PSS Layer Method in generic development process phases

In general the process in Fig. 1.10 is valid for the following cases:

- Development of a new PSS (starting at customer needs)
- Transformation of a product into a PSS (starting with a product)
- Assessment and improvement of a system (product or PSS)

Depending on the case the modelling iterations may differ.

1.4 Industrial Application Case in Detail – The Solar Home System of MicroEnergy International

The industrial case that has been chosen for the study is about the PSS offered by MEI in Tanzania. MEI, a company with headquarters in Germany supports access to microenergy systems through microfinance in several countries in Asia and Africa. The intention during the study was to improve products and services around a solar home system (SHS) implementation.

Since 2005 was declared to be the United Nations Year of Microfinance, Muhammed Yunus and the Grameen Bank got the Nobel Price for Peace in 2006 and microfinancing became well known as a successful tool to reach the poor in regions with weak infrastructure and low incomes (Yunus 2003).

Microfinance is not only an instrument that splits high investment costs into affordable monthly instalments, it is offered through microfinance institutions (MFI) that entertain a whole network with close relationships to their customers. Credit clients have to be assessed, credits have to be disbursed, instalments have to be collected and failures have to be followed up and, in the last case, guarantees have to be recovered.

MEI works closely with microfinance institutions, using their local knowledge and action network for the dissemination of microenergy systems. In Tanzania, MEI cooperates with a local microfinance institution in Kyela, a small town in the south of the country.

The pure investigation about the PSS of MEI consumed time of four full work days plus time for preparations and post-processing. The participants had an engineering background and different roles in the company. This investigation was done in various meetings under application of the PSS Layer Method. The aim was to clarify development tasks to enhance the originally planned business model including the solar system, micro credits and service provision.

1.4.1 Collation of Prerequisites

1.4.1.1 Introducing the Customers Point of View

To apply the method successfully some information on the context of the company and the customers has to be available or collected beforehand, see Fig. 1.10. Customer needs, for instance, should be clarified e.g., by market analyses. Some lead questions are as follows:

Who is my customer?

In Tanzania, MEI cooperates with local MFIs – their clients are the potential customers for the PSS.

Where is my customer? How many customers are there?

The pilot project is realized in Kyela, a small town in the south of the country. The 600 clients of that MFI are mainly cocoa farmers. They live in surrounding villages that are not connected to the electricity grid.

How can we reach our customer(s)?

These farmers are not only getting loans but also training and trading facilities for their products. They are organized in councils of 15 to 50 members. Once a month, staff of the MFI meet the councils, collect the instalments and distribute new loans. Furthermore, the councils report to the staff their specific needs for the development of their livelihood and business situation. The council meetings are a good opportunity to reach the potential customers with marketing, financing and educational activities. For installation and service activities on the solar home system, customers will have to be visited personally by motorcycles.

Acceptance of technology?

During earlier council meetings, the farmers came up with their need for electricity; especially the need to run electrical light, radio, TV, fridges and irons. Some of them had heard of solar systems and asked their MFI for support to get and finance them. To meet this request, the MFI started to look for a partner specialized in the field of rural energy supply and in this way approached MEI. Both cooperate today in a joint-venture company.

MEI proposed to start by implementing solar home systems. They are considered to be simple technology. Furthermore, they are already proven in the field; although a solar home system does not fulfilll all the needs of the customers, for instance refrigeration and ironing are not possible.

Some of the clients already operate car batteries as electricity storage and use it to run radios or TVs. For this purpose they already had some DC-wiring in their house. In this way, an important part of the solar home system technology is already known to them. New, is the solar panel, and the fact that the battery becomes a stationary accumulator. They do not have to remove it anymore for recharging. This is done automatically by the panel if the sun shines.

Willingness and ability to pay of potential customers?

The solar home system, depending on its size, costs between 350 and 800 €. MEI will offer a financing opportunity. Clients can choose to repay the loan over 12 or 18 months.

After a first marketing activity, 36 clients have applied for a loan to get a solar home system. After an internal assessment, the MFI identified 16 of them as having the ability to pay the loan back in 12 to 18 months.

Based on former experiences (Philipp and Kebir 2004), it is assumed that the applications will increase once some systems are installed and people can experience that these systems work.

The quality of the market research plays a crucial role in PSS development. Too many assumptions and missing knowledge about the customer can lead to wrong designs of product and services. A discussion on the customer's point of view can help to sensitize the designers regarding some points of view and may require further investigations before taking the last decision on product or service performance. This process can already be used to define “tasks” for the company.

1.4.1.2 The Company Point of View – Targets and Philosophy

The designers should also be aware of company targets (short, medium, long term) to apply the model successfully. This prerequisite is considered to be essential in product, service or PSS development and thus hopefully available in firms.

In the case of MEI, a short-term target is to prove the viability of the technology by a successful implementation of the first 16 solar home systems. A medium-term company target is fulfillling the remaining identified customer needs (using their energy systems for refrigeration and ironing). This is part of the strategic business plan and requires further product development activities. On a longer term all kinds of technical products and services will be offered. The long-term relationship to the customer that is developed during the repayment phase of the loan is very specific to the business model: it is not only about selling goods, but about developing a commercial infrastructure through regular services in a new, almost untouched market.

Although MEI is a for-profit-company, it considers itself as a social enterprise (Yunus 2008). The focus is to maximize the social and not the financial profit. At the same time, the project must be economically sustainable. Generated profits are reinvested to grow and develop the business.

1.4.2 Stepwise, Iterative Modelling – Detailed Discussion on Layer Classes and Modelling Results

1.4.2.1 Class "Needs" (Customer Perspective)

Description

This layer summarizes customer needs. The idea is to capture non-solution-oriented needs, for instance the need for access to broadcast information. Nevertheless, some needs will be solution- or context-related, for instance, the need to operate TV and radio with a solar home system. This layer does not contain requirements, which describe how a system function has to be designed; cp. (Ericson *et al.* 2009). The needs can be summarized, based on the outcomes of the prerequisites.

Discussion of the Class "Needs" of the Customers of MEI

The assessment regarding customer needs done by MEI have been solution-oriented. Customers want to run with their energy system lights, TV, radio, ironing and refrigerator. The non-solution-oriented needs can only be assumed as need for high social status, high quality of life, access to information, entertainment and education and the need for enablers to generate income in the evenings and early mornings.

1.4.2.2 Class "Values" (Customer Perspective)

Description

The customer value is equal to the benefit a customer gains by a deliverable. From an economic viewpoint, the value can be reduced to monetary measures in the end, but a differentiation is helpful to show differences in how PSS ideas and concepts work. The major four types of benefits are economic, environmental, social and technical benefits. Less precisely defined benefits are information and knowledge advantages, saved time or time advantage, health preservation or enhancement, prestige, measures for process robustness, agility, flexibility, etc. Briefly, the realization of competitive advantages by state protection and enhancement belong to this layer.

Discussion of the Class "Values" for the PSS of MEI

The value and benefit customers expect from a solar home system are summarized in the following:

- Economic aspects: after repaying all the instalments, customers start saving money due to the substitution of kerosene and battery recharging.
- Environmental aspects: the environmental aspect from the customer's point of view is more a security and sanitary aspect. In the case of solar home systems, the value they expect is mainly avoiding the risk of fires and dangerous inhalation of evaporated kerosene.
- Social aspects: a solar home system is an expensive technology. Due to the solar panel which is installed on the roof, it is very visible and considered as a status symbol. Furthermore, it facilitates social interaction at night, information and entertainment.
- Technical aspects: customers are getting a professional electrical installation in their houses. The solar home system is more reliable and robust than the technology that was used before. The product warranty and the service assure a long-term use of the product.

1.4.2.3 Class "Deliverables"

Description

Deliverables is what the PSS provider delivers to its customer. Deliverables can be material or immaterial. Technical artefacts, software, information, knowledge or "health" are the main deliverables. It is important, that a deliverable is a result of an activity or an activity chain, which can be interpreted as part of a service or business process. Not every deliverable has value for a customer. For instance, the delivery of out-dated information might be counter-productive for a customer. Thus it is important to differentiate between deliverables and customer values. (This layer correlates with the result dimension of services.)

Discussion of the Class "Deliverables" for the PSS of MEI

In the case of the PSS of MEI, some deliverables were already determined:

- The solar home system, a technology that will partly fulfilll electricity-related needs
- The installation of the system, including the wiring in the house

- The training to learn about how the system operates, the opportunities it opens and the limitations it has
- A financing facility: a solar loan that can be repaid in 12 or 18 months
- During financing time, the customer gets a service guaranty: once a month, when the solar loan officer comes to collect the instalment, he will look after the system, maintain it if something does not work or exchange a spare part
- All components of the solar home system have a guaranty of at least 18 months

1.4.2.4 Class "Life-cycle Activities" (Designer Perspective)

Description

This layer contains activities performed by the PSS provider and/or the customer. Activity chains result in deliverables which are supposed to have value for the customer (and of course for the PSS provider). Sometimes it can also be used to change or optimise already existing deliverables. The working principle behind this layer is comparable to process modelling or service blueprinting. (This layer correlates with the process dimension of services.)

Discussion of the Class "Life-cycle Activities" for the PSS of MEI

Figure 1.11 shows the general life-cycle of a solar home system and the related financing mechanisms.

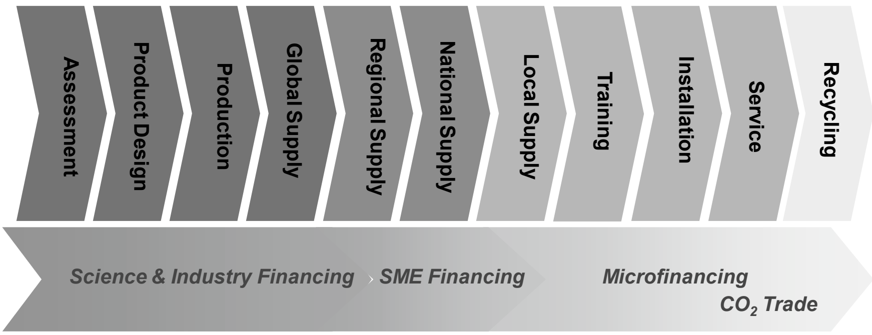

Fig. 1.11 General life-cycle of a solar home system

The financing along the life-cycle is already a first hint for the location and the different institutional forms of the involved stakeholders. For the development of the product-service system in Tanzania, the last phase, which is dominated by microfinancing, is the most interesting one. Following is a more detailed overview of the local phase that is operated by the MEI, see Fig. 1.12.

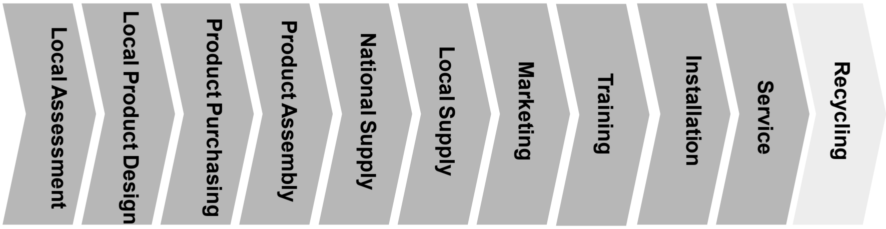

Fig. 1.12 Tanzanian life-cycle phases

The detailed product development process with the layer method required to pick out an even more detailed phase. During the workshop, the "using phase" was chosen, see Fig. 1.13.

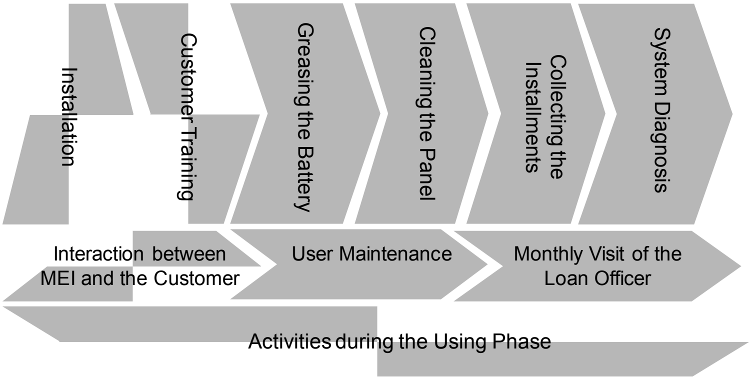

Fig. 1.13 Activities during the using phase

The phases "User Maintenance" and the "Monthly Visit of the Loan Officer", who are both parts of the "using phase", have been discussed in detail. The last one is even more detailed as Fig. 1.14 shows.

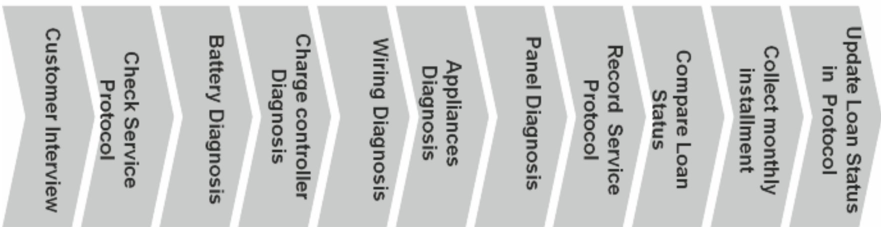

Fig. 1.14 Detailed activities during the monthly visit of the loan officer

1.4.2.5 Class "Actors" (Designer Perspective)

Description

Single actors (players), stakeholders, enterprises and enterprise units or divisions as well as even software agents are classified as actors. Actors participate in activities and they have an aim and a perception of delivered values. Software agents also have aims and interaction although they are not physical. To allow software agents to be actors might be important in case of replacing a manual executed service by a technical artefact communicating with a provider agent platform.

Discussion of the Class "Actors" for the PSS of MEI

Although a lot of actors are involved during the whole life-cycle of the Product-Service-System in Tanzania, only two have been identified being relevant during the "Using Phase":

- First, the client or one of his household members representing him. Second, the solar loan officer, a technician that has been trained in microfinance methodologies. He has to check the different technical components of the system and to collect the instalment.
- If the solar loan officer finds out during his monthly visit that there is a problem with the solar panel, it can happen that a third actor, able to climb on the roof, is required. This needs to be a man, as it is not usual in that cultural context to leave this kind of task to a woman.

1.4.2.6 Class "Core Products" (Designer Perspective)

Description

Products which have to be designed or at least offered in a package by the PSS provider are attached in this layer. The most important aspect of such core products is that they have high relevance for the final PSS value generation. Products, which have to be designed, adopted or configured viz. those where engineering tasks have to be performed by the PSS provider (network), are modelled within this layer.

Discussion of the Class "Core Products" for MEI

The core product is the solar home system consists of:

- A solar photovoltaic panel that converts solar radiation to electricity.

- A rechargeable battery (accumulator) used as storage allowing the use of electricity for 4h per day.
- A charge controller, installed between panel, accumulator and loads.
- Appliances: in general, loads consist of a few lamps and sometimes also a radio or a TV.

All components are connected through DC wiring. Specific to solar home system is their modular structure. This makes installation, maintenance and handling easy – even users and technicians with rudimental education can manage it after short training. The accumulator is the most sensitive component. It is the limiting factor as it is storing the electricity and misuse is quite easy. Fig. 1.15 shows all components of a solar home system.

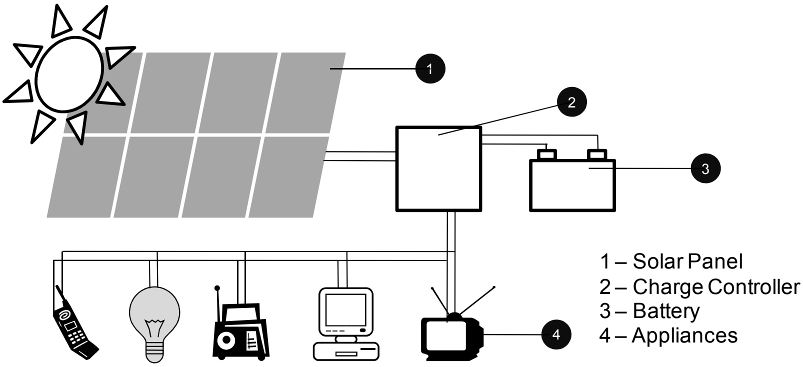

Fig. 1.15 Components of a solar home system

1.4.2.7 Class "Periphery" (Designer Perspective)

Description

Support equipment, technical periphery, tools, infrastructure, or PSS execution systems which are type of platform, outer condition, support or constraint for the PSS delivery should be captured on this layer.

Discussion of the Class "Periphery" of the PSS of MEI

Additional support equipment for the "User Maintenance Phase" has been identified. Some tasks for the company are derived:

- The clients have to grease the accumulator regularly.
  Task 1: If grease is not sold in the village, MEI has to assure access and provide it.

- If there is too much dust on the solar panel it loses capacity. For this reason, the user has to clean it regularly. For this purpose, he needs a ladder to access the roof. He also needs a cleaning set to avoid damaging the glass of the panel.
  Task 2: MEI has to make sure a ladder is available in the house of the customer or in the house of one of his neighbours.
  Task 3: MEI has to provide the cleaning set.

Also during the "Monthly Visit" equipment and related tasks for the company have been identified:

- For quality control purposes, MEI has to make sure that the solar loan officer checks all the components.
  Task 4: A maintenance check list has to be developed. It should be part of a customer card that stays at the client's house – after every check customer and loan officer have both to sign.
- MEI has to make sure that the solar loan officer is equipped with required measurement and maintenance tools. A challenge is to check the status of the accumulator and to make sure that it not misused, for example by connecting other loads or by using it more than 4h per day. Most existing tools require a whole laboratory which is not transportable during monthly visits and too expensive to be installed in the Kyela branch.
  Task 5: A manual for the loan officer, where possible failures and troubleshooting strategies are described has to be developed.
  Task 6: Find a solution for how to check the status of the accumulator under the given conditions.
- To check the panel on the roof, a ladder is again required.
  Task: Same as task 2.

1.4.2.8 Class "Contract" (Designer Perspective)

Description

As the contract is one basic element of the product-service system, remarks on the contract design should be made early to detail out the business model. Examples are the implementation of obligation, options, exception handling, duration, fines, regulations of payment, take-back conditions, warranty, transfer of ownership, responsibilities, etc.

Discussion of the Class "Contract" for the PSS of MEI

The discussion of the class "Periphery" has already been very helpful for the development of important elements of the contract between MEI and the customer:

- MEI has to provide grease and a cleaning set for the "User Maintenance" tasks.

- The “customer card” with the “maintenance check list” that has to be signed by customer and solar loan officer after every monthly visit is an important element to record the service guaranty activities during the loan repayment period.
- If the solar loan officer registers any kind of misuse of the accumulator, the customer loses the service and product guaranty.
  Task 7: The solution looked at in Task 6 “Find a solution for how to check the status of the accumulator under the given conditions” should also include a possibility to prove the misuse towards a third party.
- As long as there is no other solution to check if the accumulator has been misused, the solar loan officer has the right to look after the system any time he wants. This regulation stays in place as long as the solar home system is not completely repaid and it is still remaining in the ownership of MEI.

1.4.2.9 Class “Finance” (Designer Perspective)

Description

This layer shows when a customer is paying for deliverable(s) and how much. For instance flat rates, pre-paid, scheduled incremental payment, or payment on tickets may be possible entries. One way to model that can be simple bar charts.

Discussion of the Class “Finance” for the PSS of MEI

The “using phase” that was discussed in the workshop correlates with the “Microfinancing Phase” as shown in Fig. 1.13. Before the installation of the system, the customer has already paid a down payment of 15% to MEI. During the “using phase”, the solar loan officer collects the monthly installments and services the system as described. In this way, the customer feels the direct impact of his payments.

1.4.2.10 Class “Optional” (Designer Perspective)

Description

If there is a need to consider some special design aspects or a specific entrepreneurial view the Layer Scheme can easily be extended by layers like *Cost drivers*, *Quality* or *Law*. In the case of the PSS of MEI, the additional layer *Cost* has been used.

Discussion of the Class "Costs" of the PSS of MEI

The new tasks identified during the workshop, as, for example, providing grease and a cleaning set, are creating new costs or the development and implementation of a new solution to check and control the accumulator. On the other hand, these activities are assuring the sustainability of the system and minimizing the risks of failures.
Task 8: The new cost structure has to be integrated in the price calculation of the system.

1.5 Evaluation of the Sustainability of the System

A solar home system has a huge potential in terms of sustainability. But the deployment of these potentials is highly dependent from the implementation strategy and the business model, as discussed in the following paragraphs.

Ecologic Dimension

The use of solar energy and saving fossil fuels helps to protect natural resources. Nevertheless, accumulators are another crucial point. Without assuring a recycling procedure in the business plan, they can create a serious ecologic problem due to the acid and lead stored inside.
Task 9: Develop a recycling system for used accumulators and adapted incentives for customers.

Economic Dimension

In the long term, saving fossil fuels and developing an energy sector based on renewable energies will secure the prosperity of all societies (Scheer 2006). Still, one of the main components of the solar home system, the accumulator, consists of lead which is a limited natural resource. But while lead is recyclable, petrol, once burned, cannot be reused.

In the actual Tanzanian context, the only competition MEI is exposed to, are the retailers of fossil fuels like kerosene. But with the development of the infrastructure, the training of local technicians and the development of the market, other competitors will start offering systems as well. This development has already been seen in the Bangladesh context (Infrastructure Development Company Limited 2007).

Because the market is very small, the actual prices of the components of solar home systems are still very high. Also, here a growing market will help to cut production costs down.

The customers of MEI have a huge potential to substitute their running energy costs for kerosene and transporting and recharging batteries, but it requires that the system does not fail till it is repaid. For this purpose, MEI has introduced the product and service guaranty.

Social Dimension

The evaluation of the change in lifestyles due to the system cannot yet be done in the Tanzanian context because it needs to be observed over a longer period. The social dimension that can be taken into consideration in the described product-service system is the opportunity for a brighter distribution of solar home systems among social classes with smaller incomes due to the microfinancing system which is adapted to already existing energy expenses.
Task 10: Develop a monitoring and evaluation methodology for quality management and sustainability purpose.

1.6 Reflection and Findings

During our case study the method was customized several times resulting in the way it is presented here. The analysis helped to shed light on weak points, e.g., drivers for cost and risk, in service provision and product-use activities. Finally, new tasks for product and service design have been derived. The potential to enhance the sustainability of MEI’s solar home system has been made explicit.

1.6.1 Experiences and Opportunities

- The methodology is very supportive of the documentation and description of the solar home system. It makes important aspects explicit, particularly, the required services and their performance in the social, ecologic and economic context.
- It supports the analysis and synthesis of product-service systems.
- It is a helpful instrument to introduce stakeholders in particular parts of the business.
- The method is supportive for the development of contracts, as you can develop and discuss scenarios along the life-cycle phases.
- For the same reason, the method is helpful for the price calculation. Every activity, including supporting resources and the deliverable, can be priced and included in a simple tabular calculation.

- Precise tasks can be derived for the PSS designer or for a development roadmap. Requirements for the system design can be derived and included in the requirements list. In particular, process-related requirements or requirements on technician qualification become more tangible.
- Although the purpose is an application in early design phases (planning and conceptual design), the method can be used during the whole development process and even during the operation phase as tool for documentation, discussion and evaluation. In particular, services are changing regularly and can be adapted based on experiences during operations. In this case, the layers help to directly interlink changes with other relevant aspects like "core product", "periphery" and, in particular, "contract".
- The method is powerful in raising awareness on the importance of detailed knowledge of the customer needs and values. The method "forces" the designer to take needs and values of the customer into consideration in every step.

1.6.2 Limitations and Potential for Improvement

- The chronological orientation on the live cycle is helpful in the first step. It still has to be proved on a longer term, that it is not limiting the view as some aspects impact on different live cycle phases. Activities which run in parallel are difficult to model.
- The quality of the results is extremely dependent on the quality of the market studies done on the needs and values of the customers.
- The method does not offer a systematic way to discuss variants, so far.
- The method reflects only the point of view of the customer and the provider. The points of view of other stakeholders are not directly visible.
- The evaluation has been made in two small companies and the participants had economic and engineering experience. (Some additional experience was made in teaching.)
- omputer support of the method to transfer results easily into digital models was not available during the first two case studies. Transferring models into the computer was time consuming.

1.6.3 Recommendations

The method should be considered to be applied in workshops where product-service integration and/or customer and life-cycle orientation is important. A moderator who is familiar with the method should accompany the first application to moderate its use. This moderator needs relevant skills to lead the workshop, e.g., to collate and discuss the prerequisites and to start modelling during the discussion until the other participants understand the concept. Furthermore, he/she has to be familiar with theoretical basics of product-service systems; the other participants should have an idea of what PSS is. We assume that not more than four or five participants should attend.

Blank layer plots should be prepared beforehand. Markers or stickers to highlight important issues should also be prepared beforehand. Filled layers can be used to inform others on workshop findings and as a type of system architecture image.

Remark: as this is a relatively new result of basic research more evaluation in different branches is necessary.

1.7 Outlook

We assume that the layer method is compatible with most other PSS approaches, as it supports most basic PSS characteristic, e.g., the life-cycle perspective, the consideration of stakeholders or the need-orientation. Additional workshops will be held to investigate if this method is applicable to other PSS examples. Finally, the aim is to embed the layer model in a PSS development methodology.

A toolbox for computer support is being developed. It defines standardized elements for each layer so that the transfer of paper-based results into a digital model becomes faster. Modelling directly with computer support also becomes possible. Using the meta-model of the method as type of "product structure" will be one of the next steps. The possibility of attaching requirements, functions and project plan tasks to elements is being tested. Furthermore, export interfaces to process modelling tools are being planned.

Finally, a more comprehensive documentation including detailed modelling examples for different application cases is on the agenda.

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