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Development of knowledge-intensive product-service systems

Outcomes from the MaintenanceKIBS project

Jyri Hanski | Susanna Kunttu | Minna Räikkönen | Markku Reunanen

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[MaintenanceKIBS – Tieto- ja osaamisintensiivinen tuote-palvelusuunnittelu teollisen liike-toiminnan arvoketjussa]. **Jyri Hanski, Susanna Kunttu, Minna Räikkönen, Markku Reunanen.** Espoo 2012. VTT Technology 21. 65 p.

Abstract

Many manufacturing companies are considering the opportunities which industrial services can offer them along their core products. The development of services offers the companies new growth opportunities. The growth of technology-based knowledge-intensive business services (KIBS) has been enabled by outsourcing and globalisation, for instance. Moreover, the profitability of services is usually higher than the profitability of the other industrial businesses, and they offer profits throughout the entire life cycle of the product.

The development of integrated product-service solutions is not without challenges. Product and service design are typically accomplished separately in different organization units. Technical personnel are responsible for the development of physical products while service planning is made by the marketing organization. Consequently services are generally planned afterwards, causing problems in the compatibility of products and services. Moreover, in many cases too little attention has been paid to the business analysis of product-service systems (PSS), for example, life cycle profit evaluation or revenue logic assessment of alternative product-service systems.

In manufacturing companies, the processes related to the development of products are usually systematic, but the service development is intuitive and disconnected from the product development processes. However, the services offered and developed should be compatible with the existing product and service portfolio. Customers increasingly demand solutions from their suppliers that are comprehensive and fulfil the customer needs.

The development of product-service design processes enables the companies to design solutions consisting of the best possible combination of products and services from the perspective of the customer and the supplier. The adoption of PSS design helps the companies to take the services into account when developing products and vice versa. With the help of the new PSS design methods the lead-times of the development processes may be shortened, and better quality solutions achieved when the specific characteristics of the products and services can be taken into account as early as possible.

The goal of the MaintenanceKIBS project is to develop methods for knowledge-intensive service and product design. For instance, we provide tools and practices for concurrent design of product and service, for managing and utilizing information gathered in different planning phases and for assessing the life cycle costs and profitability of the alternative product-service-concepts.

Keywords Maintenance, knowledge-intensive business services (KIBS), product-service systems (PSS)

MaintenanceKIBS – Tieto- ja osaamisintensiivinen tuote-palvelusuunnittelu teollisen liiketoiminnan arvoketjussa
MaintenanceKIBS -projektin loppuraportti

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Tiivistelmä

Tuotannollista liiketoimintaa harjoittavat yritykset tarkastelevat yhä useammin mahdollisuuksia, joita teolliset palvelut voivat heille tarjota tuoteliiketoiminnan rinnalla. Palveluiden kehittäminen tarjoaa yrityksille sekä kasvumahdollisuuksia että uudenlaisia ansaintamalleja. Teknologiaperustaisten tieto- ja osaamisintensiivisten palveluiden (KIBS) kasvuun ovat vaikuttaneet mm. palveluiden ulkoistamiskehitys ja kansainvälistyminen. Lisäksi palveluiden kannattavuus on yleensä huomattavasti korkeampi kuin teollisuuden muiden liiketoimintojen, ja ne tarjoavat tuottoa tuotteen elinkaaren kaikissa vaiheissa.

Integroitujen tuote-palveluratkaisujen kehittämiseen liittyy kuitenkin haasteita. Tyypillisesti kone- ja laitevalmistajan ydintuotteiden suunnittelusta vastaa tekninen henkilöstö, kun taas palveluiden suunnitteluun osallistuvat yrityksen markkinointi- ja jakelutoiminnot. Tästä johtuen palveluiden ja tuotteiden yhteensopivuudessa on ongelmia ja usein palveluiden räätälöinti tehdään vasta jälkikäteen, kun tuote on jo suunniteltu. Myös tuote-palveluratkaisujen liiketoiminnallinen tarkastelu, esimerkiksi vaihtoehtoisten tuote-palveluratkaisujen elinjaksokustannusten laskenta, kannattavuusarviointi sekä ansaintalogiikan määritys, jää usein liian vähälle huomiolle.

Valmistavan teollisuuden yrityksissä tuotekehityksen prosessit ovat yleensä tarkasti määritettyjä, mutta palvelukehitystä tehdään oman toimen ohella, intuitiivisesti ja tuotekehitysprosesseista riippumattomana. Kuitenkin, tarjottavien ja kehitettävien palveluiden tulisi olla aikaisempaan tuote- ja palvelutarjoamaan yhteensopivia. Asiakkaat vaativat yhä enemmän kokonaisvaltaisia ja tarpeitaan tyydyttäviä tuotteista ja palveluista koostuvia ratkaisuja toimittajiltaan.

Tuote- ja palvelusuunnittelun kehittäminen auttaa yrityksiä suunnittelemaan ratkaisuja, jotka koostuvat asiakkaan ja tarjoavan yrityksen näkökulmasta parhaasta mahdollisesta tuote-palveluyhdistelmästä. Tuote- ja palvelusuunnittelun omaksumisen avulla otetaan tuotteita kehitettäessä huomioon myös tarjottavat palvelut ja palveluita kehitettäessä otetaan huomioon palveluiden toimittamiseksi tarvittavat tuotteet. Uusien tuote-palvelusuunnittelumenetelmien avulla voidaan päästä lyhyempään suunnittelun läpimenoaikaan ja parempaan ratkaisun laatuun, kun tuotteen ja palveluiden erityispiirteet otetaan huomioon mahdollisimman aikaisessa vaiheessa.

MaintenanceKIBS-projekti keskittyy tuote-palveluratkaisujen suunnitteluun. Tutkimuksen osa-alueina ovat tuote-palvelusuunnitteluun soveltuvien menetelmien ja työkalujen kehittäminen, eri tuote-palveluratkaisujen ja -portfolioiden arviointimenetelmät, tietointensiivisten tuote-palveluratkaisujen (KIBS) elinkaaren aikana syntyvän ja tarvittavan tiedon hallinta sekä tuote-palveluratkaisujen tarvitseman palautetiedon keräämiseen soveltuvat menetelmät.

Avainsanat Maintenance, knowledge-intensive business services (KIBS), product-service systems (PSS)

Preface

This publication is the results of the research project Development of Knowledge-intensive PSS, also known as “MaintenanceKIBS”. We thank all the people and organisations involved in this project; the steering group, the case companies and the members of the special interest group of the project, all the people who were interviewed and otherwise enabled the success of this project and the financiers who made this project possible.

The chair of the steering group was Jouko Kiiveri (Solteq) and the other members were Jaana Auramo (Tekes), Helena Kortelainen (VTT), Esa Karppi (Fastems), and Kari Hämäläinen (Normet).

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In Tampere, Finland 12.4.2012

Jyri Hanski, Susanna Kunttu, Minna Räikkönen, Markku Reunanen

Contents

1. Introduction

In recent years manufacturing companies have increasingly adopted services to be provided alongside their tangible products. These solutions, consisting of different combinations of products and services are often called product-service systems (PSS). Because of the different characteristics of tangible products and services (e.g. Cooper & Edgett 1999, pp. 14–15; Kuczmarski & Johnston 2005) special attention should be paid to the management of PSS.

According to the interviews conducted for this project, most of the bigger companies in the manufacturing industry have vast amounts of information on their products and clearly defined product development practices. However, the service development is conducted with little or no systematization, although systematic development practices exist in the literature (also in Aurich et al. 2006 and Bullinger et al. 2003). PSS development in particular is more or less an intuitive process.

The commonly used product development models (e.g. Ulrich & Eppinger 2003; Cooper 1993) are not designed for the development of services. In the development of services strong customer, supplier and employee input is needed, and the development should be iterative and flexible (Panesar & Markeset 2008).

In the case of PSS, the development of both the product and the service part must be taken into account. When developing PSS, both the development of products and services should be defined and systematized and the systematic processes should then be integrated (Aurich et al. 2004).

Typically the service development is concentrated on the delivery processes of the product (see Figure 1). One important goal of this project was to take the service perspective into account at an earlier stage of the product development process. Ideally, the service development would start at the very earliest stage of the innovation process, the Front End of Innovation (FEI). Based on the needs, products and services of the company, the companies may develop their PSS to be product driven, service driven or in a balanced way, where the product and service components are seen to be equal.

The main objective of MaintenanceKIBS was to create a knowledge-intensive product-service business development approach and model. In order to achieve this objective, several methods were proposed for the whole life cycle of product and service. Figure 1 summarizes the outcomes of this project. The front end processes include the creation of new ideas, and the collection and evaluation for instance, of problems, improvements or needs identified. The new ideas are then further developed in the R & D processes, which should be more formal and systematized than the front end of innovation. In the MaintenanceKIBS project, the focus in the portfolio management phase is on the product-service systems. In this phase, the existing solutions are analysed, evaluated and managed to streamline the portfolio with the strategies and business models of the company. The portfolio management practices may reveal the possible deficiencies in the offerings of the company. The solutions created in the earlier phases of the PSS development are delivered to the customer in the delivery processes. Running simultaneously with the development processes are the life cycle management processes, which are intended to manage all the relevant information created and needed in the various development stages.

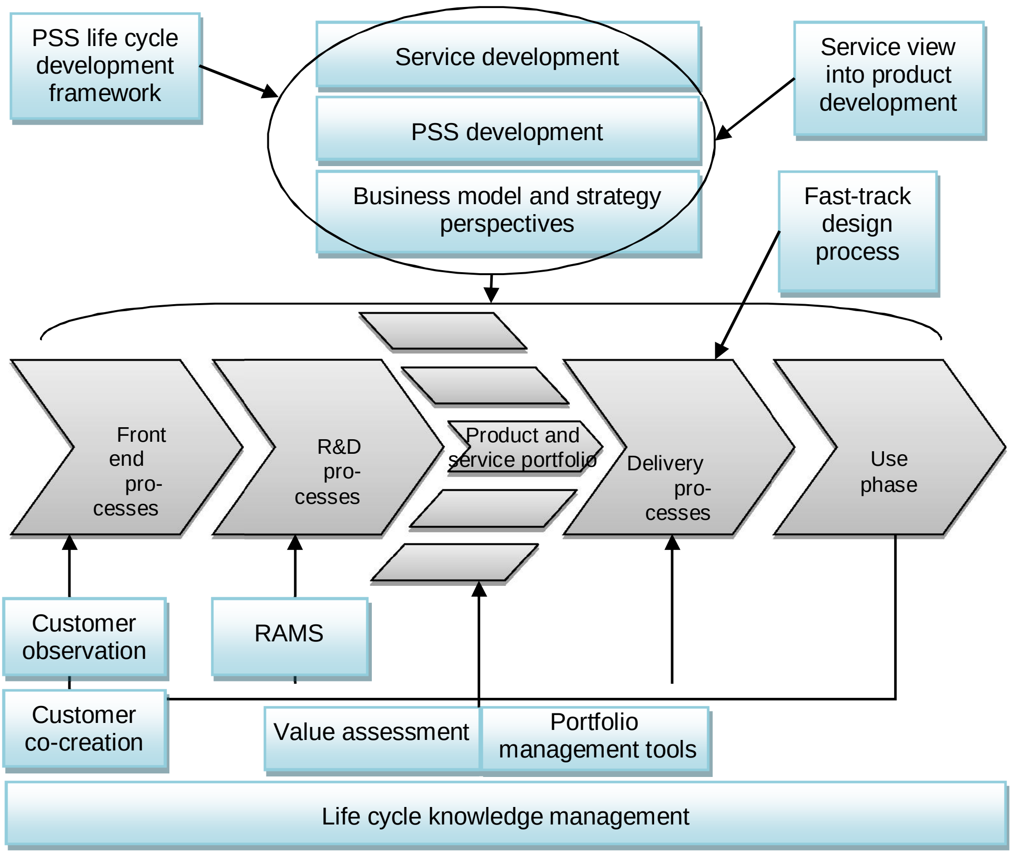

Figure 1. Overview of the outcomes of the MaintenanceKIBS project. Proposed methods and tools (blue boxes) to be applied at the various stages of the product and service life cycle (grey arrows).

The main research questions for the project are as follows:

1. What is the state of art in PSS development?
2. What kind of knowledge is needed in the first stages of PSS development and how to gain access to this knowledge?
3. How can the PSS portfolios be evaluated?
4. Which sources and needs of information could be a basis for new knowledge-intensive business services (KIBS)?
5. What kind of PSS development model would be suitable for industrial companies?

The first goal of the project was to provide a state of the art review on PSS and PSS development processes. To know more about the state of the art of PSS, interviews were conducted among Finnish companies and a literature review was made. Various product, service and PSS development process models found in the literature were also discussed to introduce new elements into the existing product and service development processes. Chapter 2 contemplates these topics in more detail.

In Chapter 3, the focus is on the front end of innovation and the information needed for that stage. The emphasis is on the business environment, production environment and customer based information. The role of customer based information in the development of products and services is addressed applying two methods: customer observation and customer co-creation.

Chapter 4 discusses the management of PSS portfolios. The portfolio management chapter includes business model and value assessment perspectives. The value assessment part concentrates on the assessment of service value. The value assessment model created combines qualitative and quantitative methodologies. In order to choose an optimal combination of products and services for a PSS, the portfolio analysis model is discussed in this chapter. The portfolio analysis model is used in concurrent product and service development to identify and assess the risks, benefits and profitability of the portfolio.

Manufacturers typically provide services which are based on the manufacturer's knowledge of their own equipment. The value and significance of knowledge-intensive business services (KIBS), including knowledge-intensive maintenance services, is steadily growing in modern industries. Thus data and its collection were important viewpoints in our project. To find out the possible information sources and information needs that could serve as a basis for new KIBS a hierarchical life cycle model of different information needs is presented in Chapter 5. In this chapter the management of RAMS perspectives in the early stages of the PSS development is also addressed. In Chapter 6, we conclude the Maintenance-KIBS project and present some recommendations for industry and academia.

2. State of art of PSS

2.1 PSS definition

In today's business environment there are not many companies that offer only services or products, but instead offer a mix of products and services (Cooper & Edgett 1999 p. 20). The development of a pure product without additions or a pure service without a physical part is becoming rare.

The term product-service system (PSS) first surfaced in the mid 1990s and originates from environmentalist driven authors (Tukker & Tischner 2006). The environmentalists argued that without some way to detach economic growth from environmental pressure mankind would most likely face a disaster (von Weizäcker et al. 1997). It was realised that the shift of focus from products that fulfil the customer need to the final customer need could greatly improve sustainability (Schmidt-Bleek 1993). The sustainability connection of PSS is also highlighted in standards (e.g. ISO 26000, 2010). During the same period, the business literature started to show some interest in functional business models; companies started to offer integrated solutions in order to meet final customer needs. By so doing, the companies were able to improve their position in the value chain, improve their innovation potential and enhance the value added of their offerings. (Tukker & Tischner 2006, Wise & Baumgartner 1999)

Different definitions of product-service system are presented in Table 1. The concept of PSS rests on two pillars: The starting point of business development is the final functionality or satisfaction that the customer wants, instead of the product that would potentially satisfy customer needs. Instead of taking the existing structures, routines and the position of the firm for granted, the final functionality should be provided with an open minded, “greenfield” mindset. (Tukker & Tischner 2006)

Table 1. Definitions of a product-service system.

Author	*Definition: A PSS...*
(Goedkoop et al. 1999)	is "a marketable set of products and services capable of jointly fulfilling a user's needs"
(Mont 2001)	is "a system of products, services, networks of actors and supporting infrastructure that is developed to be competitive, satisfy customers and be more environmentally sound than traditional business models"
(UNEP 2002)	is "the result of an innovative strategy that shifts the centre of business from the design and sale of (physical) products alone, to the offer of product and service systems that are together able to satisfy a particular demand"
(Tukker & Tischner 2004)	"consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs"

The product-service ratio of PSS can vary from pure product to pure service as shown in Figure 2. Tukker (2004) presents three main categories of product-service systems, which are product oriented, use oriented and result oriented PSS. Moving from the first type of PSS to the last, the role of the product as a creator of value diminishes and the provider has more and more freedom in fulfilling the true need of the customer.

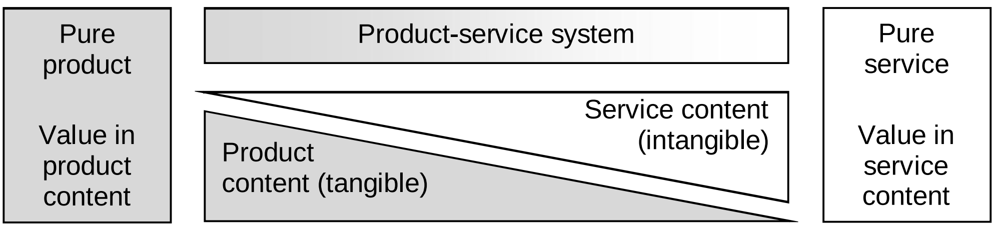

Figure 2. Variation of product-service content (adapted from Tukker 2004).

The first type is product-oriented PSS, where services are add-ons to products. This is traditional selling of products with product-related services, such as maintenance, repair or operator training. The second type is use-oriented PSS, where the customer buys the use or availability of a product (e.g. leasing) and the assets are owned by the producer. In the third type, result-oriented PSS, the assets also remain the property of the manufacturer, and the customer buys results or capability and pays for the provision of agreed results.

Offering product-service systems has many benefits, for both providers and customers. The possible benefits of PSS from the companies' and customers' perspective are presented in Table 2 and Table 3.

Table 2. Benefits of product-service systems from companies' perspective.

How do product-service systems benefit companies?	*Author*
• PSS enable fulfilling customer needs in a more intelligent and efficient manner	van Halen et al. (2005), Baines et al. (2007)
• PSS calls companies to increase the value to customers at lower production costs, lower material inputs and reduced emissions	van Halen et al. (2005), Baines (2011)
• Competing with PSS forces companies to constantly improve their capabilities to respond to the changes in the environment: o competitive advantage which is difficult to imitate	van Halen et al. (2005)
• Strong relatedness to customer needs: o chances to re-think their business for companies o enabling radical forms of innovation o good feedback to product and service development, increased knowledge about the working environment	van Halen et al. (2005), Baines et al. (2007), Alonso-Rasgado & Thompson (2006)
• PSS has also great potential to improve the position of the company in the value chain and thus: o improve the profit margin o create unique client relationships	Tukker & Tischner (2006), Baines (2011)
• PSS provides strategic market opportunities and an alternative to mass production and standardisation to manufacturers	Baines et al. (2007), Baines (2011)
• Image benefits (lean and efficient company)	Alonso-Rasgado & Thompson (2006)
• Steady cash-flow	Alonso-Rasgado & Thompson (2006), Baines (2011)
• Complying with legal or corporate obligations	Baines (2011)
• Taking advantage of taxation laws	Baines (2011)

Table 3. Benefits of product-service systems from customers' perspective.

How do product-service systems benefit customers?	*Author*
• In comparison to products, PSS brings value to customers by…	
o increasing the level of customisation	Tukker & Tischner (2006),
o reducing the customer's effort to make the product work	Baines et al. (2007)
• PSS has a potential to provide higher levels of quality in comparison to products	Baines et al. (2007)
• A predictable periodic expenditure instead of high capital investment	Alonso-Rasgado & Thompson (2006), Baines (2011)
• Level of availability guaranteed (risk management), equipment in good working condition	Alonso-Rasgado & Thompson (2006)
• Up-to-date equipment guaranteed	Alonso-Rasgado & Thompson (2006), Baines (2011)
• Complying with legal or corporate obligations	Baines (2011)
• Taking advantage of taxation laws	Baines (2011)
• Improved cost control and reduced operating costs	Baines (2011)
• Focus on core competencies	Baines (2011)
• Reduced risk of adopting new technologies	Baines (2011)

Figure 3 presents three different product-service system strategies. The first and the most common category in the manufacturing industry is liability driven strategy. In this strategy the product design processes are very systematic whereas service design is highly intuitive. The emphasis is on the development and manufacturing of innovative and reliable products. The second category of PSS strategies is function driven strategy. The product and service design are systematic and the role of the services is to enhance the products. The emphasis remains on product. Products and services are not viewed as separate species and can be combined to form different variants according to customer needs. The third and final category of PSS strategies is use driven strategy. In this strategy the service design elements are integrated into the product design process. The aim of the strategy is to provide an individual and demands fulfilling solution for the customer that consists of inseparable tangible and intangible components. (Aurich et al. 2004)

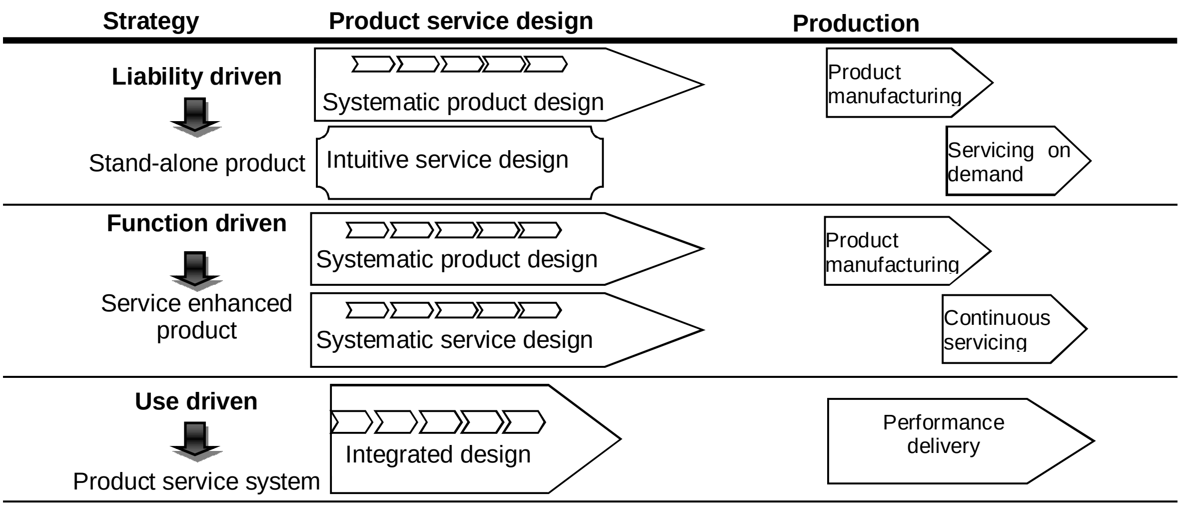

Figure 3. Product-service system strategies (Adapted from Aurich et al. 2004).

Liability driven strategy demands well-structured product design processes: existing product design activities, organisational standards and information exchange are analysed. Manufacturer-user relations, especially mutual influences on product design, should also be addressed. These steps lead to a systematised product development process. Function driven strategy adds a similar systematic approach also to the service development process. A systematic service development process can then be achieved by integrating all service characteristics into the product development. In order to reach the third and final category, use driven strategy, both processes must be integrated by means of analysing the overlaps and aligning information exchange and organisation. (Aurich et al. 2004)

2.2 Interviews

In addition to the literature review, interviews were conducted with eight Finnish companies to achieve an understanding of the current situation concerning product–service systems. The companies were selected on the basis of their own interest in the topic and their willingness to be interviewed. The companies interviewed were mostly manufacturers which have earlier concentrated on physical products the main after-sales service being the sales of spare parts. Currently, all companies offer services which cover at least their own products, and most have plans to expand their service business.

The interviews were conducted between February and May 2010. The main focus of the semi-structured interviews was on methods used to design services and tangible products. However, we also included other questions to gain a better understanding of each company as a product–service provider. The topics and sub-topics of the questions covered are presented in Table 4. The interviews lasted between two to four hours each.

Table 4. Structure of the interviews.

Topics	**Sub-topics**
Company background	Name, branch, turnover, number of employees, number and locations of premises
Tangible products	Product range, tailoring of products
Services provided	Definition of service, services and service concepts provided, volume of services, future plans about services
Designing products and services	Methods used, methods for concurrent design of product and services, utilization of feedback data, problems identified
Identifying customer needs	Methods used to identify customer needs, methods to convert customer needs to requirements for products and services, when customer is involved in design of product or service
Network of subcontractors, partners, customers, etc.	Extent of network, collection of feedback from network
History data about products and services	Collection and utilization of data on field experiences
Value of services	Methods to evaluate the value of services provided

The maintenance of their own products was the main service in all companies. When looking at the top level, there were only slight differences between the services provided. The content of services varied according to the branch of industry and the servitization level of the company. Product-oriented services are clearly the predominant service type in the companies interviewed. A large part of the services mentioned in the interviews can be categorized as knowledge-intensive business services (KIBS). (Kunttu et al. 2010). KIBS may be defined as services which provide knowledge-intensive inputs for the business processes of other organizations (Miles 2005).

Systematic service design processes were typically not described; only one company had defined their service design process and its content. In other companies, new service designs were created more or less case by case without a predefined procedure. Typically, ideas for new services come from customer needs articulated. At the beginning, a new service is tailored for one or a few customers, and if greater demand for the service becomes apparent, it can be further developed into a new service product. (Kunttu et al. 2010)

It may be said that the design processes of services and products live their own lives in their own departments. The interviews revealed that co-operation between product designers and service designers is typically limited to only a few joint meetings. However, the companies generally considered this co-operation beneficial to the outcome. (Kunttu et al. 2010)

According to the companies, use based information is collected systematically in the form of feedback on product use, faults and customer satisfaction. The utilisation of the information is hampered by the fact that in many companies it is scattered over many systems and personal Excel charts. The feedback is mostly machinery related and comes from inside the company and usually from people operating in the customer interface. (Hanski 2011)

In general, the companies find that current customer needs are recognised well as the employees working close to the customer provide help in defining the needs. However, recognition of future customer needs is considered lacking as the customers are unable to articulate them. There are different opinions considering the role of the customer as some emphasise the role of the customer as the source of future customer needs and others find the customer a source of present needs. The methods used in the recognition of customer needs are market research, competitor analysis, pilot projects, customer satisfaction survey and discussions with customers. There are, however, substantial differences between the companies regarding the methods; some have no specific means of recognising customer needs and some train their sales staff to identify customer needs and were considering also involving their maintenance staff in the identification of customer needs. (Hanski 2011)

All the companies found that the customer should be included at an early stage of development, ranging from the idea generation phase to the piloting. Co-operation is made with key customers, mainly in the development of products but in some cases also in service development. After the delivery of the product, most companies send a customer satisfaction inquiry. The customer contact is more intense with those customers having a warranty and/or service contracts. (Hanski 2011)

There were systematic methods for analysing and utilising customer based knowledge in half of the companies. The analysis and utilisation concentrated on the maintenance reports in ERP and CRM systems, but one company used customer knowledge systematically also in requirement specification. (Hanski 2011)

Figure 3 outlined the three product–service system strategies; liability driven, function driven, and use driven. In accordance with this classification, all the companies were on the first level for product and service design. Product design was systematic and well-structured but service design was mainly non-systematic and intuitive. Interest in service business had been high among companies and the paucity of service design did not equal the paucity of service provision. All the companies had defined their service concepts and respective content. So far, new services had mainly been developed in line with customer requests, and the content of each service had been defined on a case-by-case basis. The services with the biggest potential had been formed as service products also to be offered to other customers. In this way, services had been developed and provided for at least ten years in the companies interviewed, and had led to a wide range of individual services which had been combined into service solutions/contracts. Thus, it can be said that the services met the characteristics of the function driven strategy in Aurich's classification. (Kunttu et al. 2010)

The interviews yielded several important findings. Information based on usage of products and services could be utilised better. The use-based information in the companies interviewed was in the form of feedback from employees, fault information and surveys. These sources were not necessarily sufficient to obtain a comprehensive picture of how the products and services were used. The collection of all the scattered information under one system and using the system from the very beginning of the idea generation throughout the whole life cycle would be beneficial for the companies. Companies would benefit from richer forms of information. (Hanski 2011)

The companies interviewed were obviously only a small sample of all manufacturers providing services in Finland, and the results cannot be generalized to concern the whole industrial sector. Nevertheless, the results are congruent with our preconception that practical tools and methods are needed for the concurrent design of products and services. Baines et al. (2009) and Uchihira et al. (2008) arrived at the same conclusion.

According to the literature review there are very few published PSS design methodologies available. One reason is that the need for integrated design only arose just over a decade ago, when industrial services began to play a more important role in manufacturing industry revenue. There are some widely accepted product design methodologies and also some methodologies for service design, but the integrated view is not yet common. The lack of integrated methods was also seen in the interview results. (Kunttu et al. 2010)

2.3 PSS development methods and tools

Defining a standard set of methods and tools to design PSS is said to be virtually impossible (Morelli 2006). Despite this, it is possible to formulate a general model for PSS, i.e. "a toolbox", as proposed in the literature. The toolbox contains suitable tools for different customer needs and for different products supported. As seen in Figure 1, the toolbox of this project includes tools for the entire product and service life cycle.

There are several integrated product and service development frameworks available in the business literature. In this report, we present the models and methods of Alonso-Rasgado & Thompson (2006), Aurich et al. (2007), Mannweiler & Aurich (2011) and the SAE standard (SAE J817-2 1991).

2.3.1 Integrating a service view into product development

The maintainability index in SAE J817-2 standard (1991) can be used as a basis for integrating service design elements into product development. The application of the index is a step towards integrated product and service development. It is especially beneficial for manufacturing companies who maintain their machinery or offer maintenance services. Even though the standard concerns mainly off-road work machines, the presented serviceability aspects can, with minor adjustments, also be applied to manufacturing of various engineered products.

In the maintainability index, the machines are assessed in terms of location, access, operation and other miscellaneous considerations. The operation category has several subcategories, for example, component checking, lubricating and cleaning. The different maintenance operations needed are given different scores (the easier the maintenance operation the better score it will get). An example of cleaning considerations is presented in Table 5. (SAE J817-2 1991)

Table 5. Operation considerations, cleaning (SAE J817-2 1991).

Cleaning	*Points*
Blow with air	3
Single bath wash	5
Multiple bath wash or wash and oil	10
Clean reservoir by solvent spray or similar technique	10

To obtain the real maintainability score for the system, all the scores from performing the maintenance operations must be multiplied by the frequency multiplier and also by a quantity multiplier when repetitious (nearly identical) items make it appropriate (SAE J817-2 1991). The frequency multiplier chart is presented in Table 6.

Table 6. Frequency multiplier chart (SAE J817-2 1991).

Maintenance interval	*Frequency multiplier*
1000h – semi-annually, or greater	1
500h – quarterly, or as required	2
250 h – monthly	4
100 h – semi-monthly	10
50 h – weekly	20
10 h – daily	50

As a result, the system, its parts and the factors affecting the system are analysed in terms of their reliability, availability, maintainability and safety (RAMS). The higher the total score, the more carefully the item should be scrutinized. The items with the highest total scores are those most likely to be skipped by the serviceman, because they are difficult to reach and maintain. Thus, improvement in these areas can reduce the risk of neglecting related components or machine failure and also the machine downtime during periodic maintenance. An example of a system checklist is presented in Table 7. (SAE J817-2 1991)

Table 7. Design for Service (DfS) checklist example. Adapted from (SAE J817-2 1991).

Items	Service required	Location	Access	Operation	Misc.	Quantity multiplier	Frequency multiplier	Item total	Comments
Engine air cleaner	check	0	0	0	0	0	0	0	No points
Fuel tank	fill	1	4	4	0	1	50	450	Overfill runs down outside of machine
Cooling system	level check	2	4	4	100 (r)	1	50	5500	(r) maintenance guide calls for caution
Engine oil	level check	1	1	3	0	1	50	250	
Engine valves	adjust	15	15/15	4	10/10	1	2	138	
Hydraulic oil	drain	25	4	8	2	1	1	39	Non-standard (800 hr) interval
Hydraulic oil	fill	15	3	8	0	1	1	26	Non-standard interval

In this example, serious attention should be paid especially to the cooling system which scored 5500 points. The fuel tank, engine oil and engine valves were also among the high priority items.

2.3.2 Fast-track design process

The fast track design process is described in Alonso-Rasgado & Thompson (2006). Its main goal is to shorten the calendar time needed for discussions between customer and supplier and is thus applicable in the delivery phase presented in Figure 1. The other objectives of the fast-track design process are:

- clarification and provision of a methodology for interactions between customer and supplier that lead to the creation of a product-service system
- informing the customers about the value of the PSS
- reducing the time that it takes for producing a contract proposal
- providing an efficient, lean and capable image of the supplier
- providing the supplier a rapid way to implement new products and services

- adding value to the product in the early stages (Alonso-Rasgado & Thompson 2006).

The fast-track design process can be broken down into five distinct stages:

- Stage 1. Business ambitions of the client
- Stage 2. Potential business solution
- Stage 3. Core definition of total care product plus total care product options
- Stage 4. Enhanced definition of the potential total care product
- Stage 5(i). Business case risk analysis of options
- Stage 5(ii). Business case validation and evaluation of alternatives. (Alonso-Rasgado & Thompson 2006)

During the first stage the customer and the supplier go through an iterative process, where the needs and requirements of the customer should become apparent. The preliminary product-service system architecture (what kind of solution would suit the customer the best) is discussed and the value added from the PSS is presented to the customer. The first hardware definitions should also be conducted during this stage. (Alonso-Rasgado & Thompson 2006)

The second stage consists of creating potential business solutions and informing the customer about their advantages and disadvantages. The needed subsystems are made clearer to the customer. During the third stage the PSS solution most suitable for the customer is identified. The core of the most suitable PSS is defined and pricing begins. In the fourth stage, the core definition is enhanced and the focus is on the details of the PSS. Pricing is more accurate and the proposed PSS can be graphically presented. (Alonso-Rasgado & Thompson 2006)

In the fifth stage, the risk assessment is performed from both the supplier's and the customer's point of view. For the supplier, the risks include the commitments to the customer over an extended period of time (e.g. financial penalties, resource requirements). For the customer, the risks include the supplier's ability to perform well enough for the customer to be competitive, the penalties and costs of changing a supplier, and the stability of customer-supplier relationship. After the risk assessment, the business case can be validated by modelling all the service, product and money flows with the PSS stakeholders. The product-service systems are long-term arrangements. Their goal should be to ensure sound business to all the companies participating in the value creation process in case of upturns and downturns in demand. (Alonso-Rasgado & Thompson 2006)

2.3.3 Life cycle development framework and the configuration process of PSS

The PSS life cycle development framework is one of the few frameworks addressing the whole PSS development process. The framework by Aurich et al. (2007)

consists of four phases: Organisational implementation, PSS planning, PSS design and PSS realisation. The framework is visualised in Figure 4. In the organisational implementation stage, the foundation is laid for the necessary design and realisation processes. This stage includes the definition of responsibilities and organisational units as well as the standardised processes for the product, service and the concurrent product and service development.

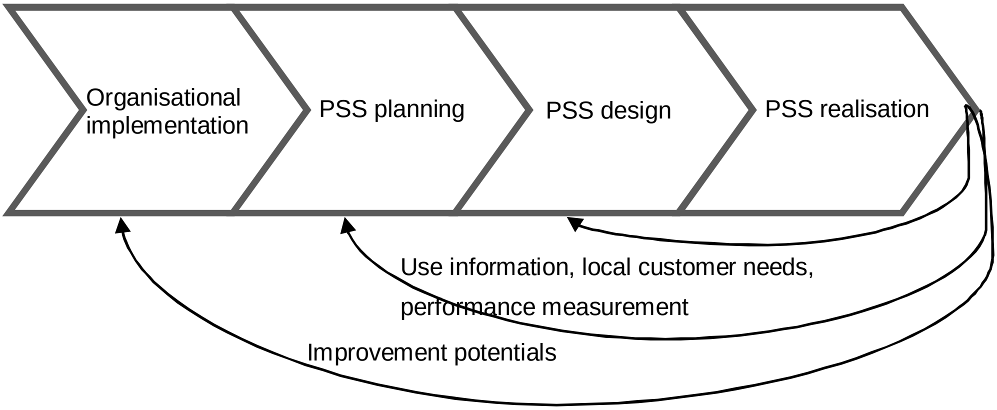

Figure 4. PSS development framework (Aurich et al. 2007).

The goal of PSS planning is to identify, evaluate and select the ideas for new PSS that could be further developed. Ideas may come from both inside and outside the company. The ideas should take the specific customer and market requirements as well as the company's strategy into account. In finding the ideas, Aurich et al. (2007) propose a dual process. At first, the physical core of the product is defined. The possible service ideas are then attributed along the product's life cycle from customer's point of view. Secondly, the ideas are evaluated against external customer and internal manufacturing targets. The expected influence of the service ideas on the product core is assessed. Finally, promising ideas are selected and sent for PSS design.

The PSS design phase includes the description of product and service components and their relations as well as the definition and the execution of the development project. The components are adapted to the local markets with the help of frontline employees. As a result, the PSS and the processes needed for the execution of the PSS are described. (Aurich et al. 2007)

In the final phase, PSS realisation, the emphasis is on providing the customers with the desired configuration of products and services and on establishing feedback loops to facilitate the process of continuous improvement. Activities in PSS realisation include configuration of PSS to local customer needs, performance measurement and collection of use information. (Aurich et al. 2007)

Mannweiler & Aurich (2011) present a model for configuration and the tools supporting the creation of the PSS offering in Figure 5. The prerequisites for a successful configuration process are a standardised description of products and services and their interdependencies. Thus the model of Mannweiler & Aurich (2011) is the most beneficial in delivery portfolio management and in the delivery phases of the PSS process, where the solution is already mostly developed and needs to be customised to the needs of the customer (see Figure 1). The phases of the configuration process are requirements gathering, configuration and purchasing phase.

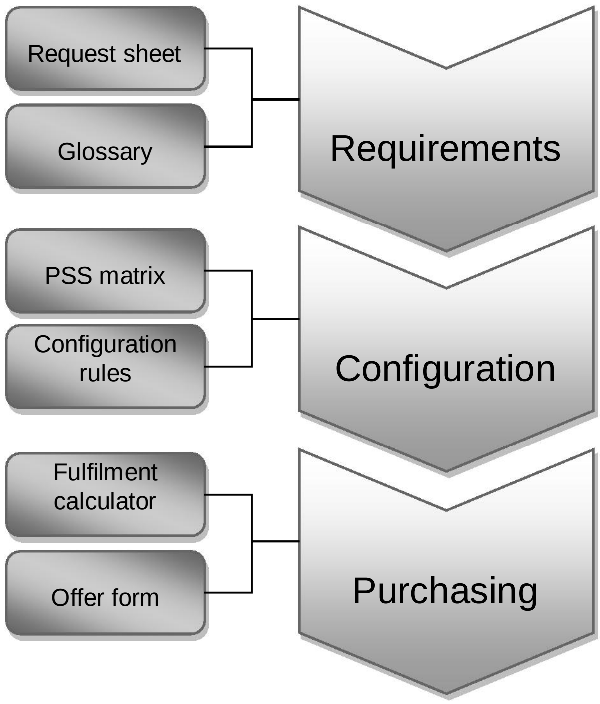

Figure 5. PSS configuration process and the supporting tools (Mannweiler & Aurich 2011).

The requirement gathering phase consists of three steps, namely systematic customer interview, transformation of requirements into technical properties and presentation of transformed requirements to the customer (Mannweiler & Aurich 2011). The objective of the first phase is to gather the customer needs and requirements, and so to begin the co-creation of the PSS with the customer. Mannweiler and Aurich (2011) propose that useful tools during this phase would be a request sheet (for transforming customer requirements into technical requirements) and a glossary (a list of customer requirements).

The configuration phase also consists of three steps. In the first two steps the product and service are configured. The third step is about the PSS configuration i.e. the product and the service parts in the PSS offering. The final phase, purchasing, concerns the degree of PSS fulfilment, PSS life cycle costs and resource analysis for the whole life cycle. (Mannweiler & Aurich 2011)

The methods and models presented provide a good starting point for developing PSS development models in companies. However, in order to capture more substantial benefits of the PSS development, the development processes need information on business and production environments, and on customers.

3. Sources of knowledge for the front end of the innovation process

The early concept development and design phases (i.e. the front end) of the innovation process are somewhat unstructured and uncontrolled. Even though methods and tools have been created for the management of the front end of the innovation process (e.g. Paasi & Valkokari 2010), there is so far not much experience of systematically providing these early phases with adequate amounts of analysed information. (Ahonen et al. 2011)

Companies need both external and internal sources of information in order to be competitive (Chesbrough 2003). The internal ideas may come, for instance, from the R & D department, sales, marketing and production. External ideas may come, for example, from customers, competitors, suppliers, consultants and scholarly sources. The possible tools and media include market analyses, customer satisfaction surveys, tracking of intellectual property rights, scientific publications, feedback and discussions with customers, suppliers and experts. (Hanski & Reunanen 2012)

Customer is seen as one of the most important sources of information and ideas (Panesar & Markeset 2008). The conventional marketing research tools, such as interviews, focus groups and surveys, do not capture the latent needs of the customers and seeds of the radical ideas well enough (Slater 2001, Matthing et al. 2004). Observing users or customers in their natural environment and active customer participation are seen as a source of latent customer needs and new ideas as well as ways of better exploiting the customer contacts (von Hippel 1986, Leonard & Rayport 1997, Sawhney & Prandelli 2000, Dahan & Hauser 2002, Rosenthal & Capper 2006).

3.1 Business environment, production environment and customer based knowledge in the front end

Customers are often unable to articulate their future needs and the PSS provider needs to ensure that an appropriate amount of data is gathered in order better understand customers' business. The front end processes integrate the data and ideas gathered in order to refine the ideas into promising concepts of products and services. They result in concepts ready to be incorporated into the new product or service development processes (R&D stage). The front end of innovation is iterative in nature and also includes evaluations of whether ideas will be further developed into concepts, rejected or put on hold. Finally, a decision on whether a concept will be selected for further development within a specific new product development (NPD) or new service development (NSD) project must be taken. (Ahonen et al. 2011)

Figure 6 presents the knowledge needed in the front end of the service innovation process. The main categories of information to be considered when gathering new customer knowledge for the development of new innovative PSS concept are business environment knowledge, and customer and production environment knowledge.

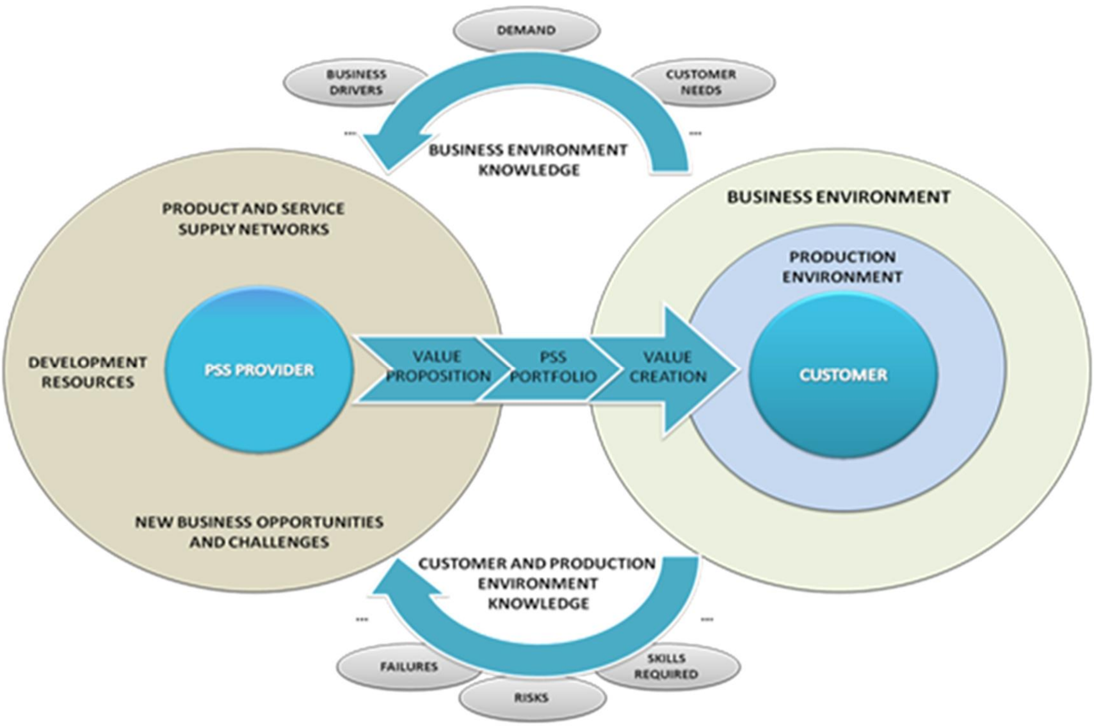

Figure 6. Knowledge for the front end of the service innovation process (Ahonen et al. 2011).

The important knowledge needs in the business, customer and production environments are presented in Table 8. (Ahonen et al. 2011)

Table 8. Knowledge needs in the front end of innovation.

Business environment knowledge	**Customer and production environment knowledge**
Business drivers and success factors (capacity, cost efficiency, quality, safety, non-failure policies etc.)	**Criticality and production structure** (identification of bottlenecks)
Life cycles of the customer's plants (implementation, normal production phase, ageing but continuously invested in or ageing with consequences to production efficiency)	**Need for preventive and corrective maintenance** (required level of maintenance, characteristics of the environment, stresses caused by production etc.)
Fluctuations in demand (diversity of the product and service offering may help)	**Complexity of maintenance** (complexity of equipment, structure, technology, maintainability etc.)
Economic situation (demand and position in the market)	**Opportunities for carrying out maintenance** (amount of time that can be used for maintenance activities)
Maturity of the industry and products (fast-growing field is a great ground for innovations but at the same time challenging)	**Risks** (risks caused by failures and occupational risks should be analysed and managed)
Changing customer needs and future challenges (current and future market requirements and customer demands)	**Demand for knowledge and skills** (special tasks and technology)
	Need for investments (historical information, knowledge on trends of failures etc.)
	Failure behaviour (life cycle phase of the production equipment, maintenance and investment history, overloads etc.)
	Customer's organization (customers' know-how, capabilities, resources, reactions, development plans etc.)

3.2 Customer observation method

The customer observation method was designed to better capture customer based ideas and information from customer contacts. The method is presented in Figure 7 and is based on Hanski (2011) and Hanski et al. (2012). The method focuses on the employees with customer contacts. In order for the method to be successful, several prerequisites have to be taken into account. The prerequisites of the customer observation method include creative and optimistic employees who have prior knowledge related to the observation and customer contacts. These prerequisites should be managed and supported by an appropriate organisational culture, which supports the generation and transfer of new knowledge, and the education of employees. When these requirements reach a high enough level, an observation is made.

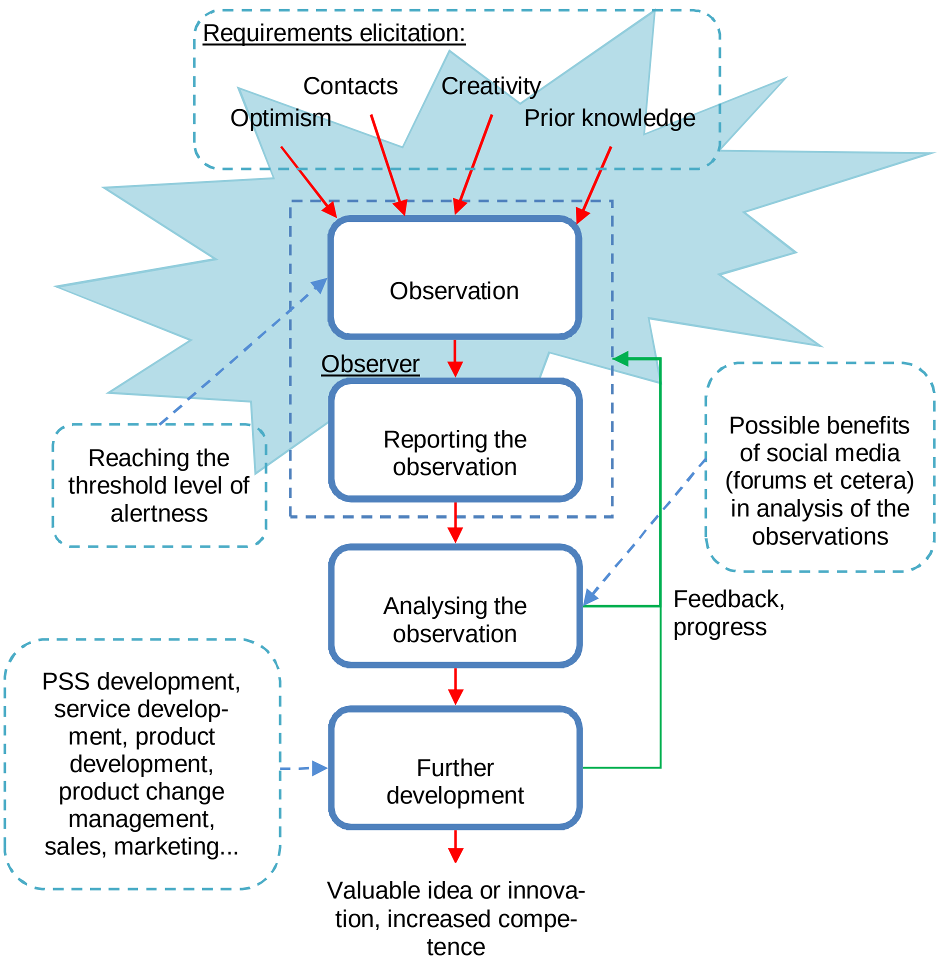

Figure 7. The customer observation method (Hanski et al. 2012).

After the observation has been made, the goal is to make the observation visible to those who would benefit from it. In making the observation visible, as well as in the other stages, ease of use is a decisive factor. Existing information systems should be used if possible. The shared observation is analysed by specified people and sent for further development. Feedback should be given to the observer to enable the observers to send the next observation. The observation may be submitted to a common forum for discussion and further development.

Testing of the method revealed that it is a good source of information on customers and ideas, although further testing would be needed to confirm all its possible benefits. In addition to these benefits, it can be argued that the adoption of customer observation increases the communication inside the company and also between the customers and employees. Further, the possible benefits include closer customer relationships and improved competencies resulting from increased knowledge of the problems of the customers, the solutions that could help the customer and improved communication.

3.3 Customer co-creation

Customer co-creation can be defined as co-operation between a company and its customer. The customer is an increasingly important partner not only as a buyer and a source of information but also in value creation (Prahalad & Ramaswamy 2000). Innovation project members can gain new and diverse viewpoints through intimate and frequent communication and contact with customers (Jongbae & Wilemon 2002).

The business literature discusses the customer co-creation, including its benefits and opportunities, mainly from the economic perspective. However, when analysing the manufacturing industry and its complex manufacturing networks, the economic perspective alone may not be sufficient. The economic perspective should to be complemented with the social and environmental perspectives, which together form the sustainability perspective. Taking all the perspectives of sustainability is also consonant with the concept of PSS. In the bigger picture, customer co-creation may help companies to achieve their sustainability goals. (Hanski & Reunanen 2012)

Kausch (2007) argues that the benefits of customer integration should not be taken for granted and every case of co-creation with a customer should be individually assessed by the decision-makers. The opportunities related to customer co-creation are presented in Table 9.

Table 9. Opportunities related to customer co-creation in the front end of innovation (Hanski & Reunanen 2012)

Opportunities
• access to new knowledge
• strategic advantages
• increases innovation potential of a company
• stronger customer relationship
• better understanding of market needs, size and growth
• fewer errors in the front end of innovation (FEI)
• better product quality
• improves competencies and capabilities of the employees and the company
• helps in generating, selecting and testing of ideas, shorten the FEI cycle
• reduced consumption of energy and materials in production and use, optimal life cycle costs (economic, social and environmental perspective)
• more attention to recycling and disposal in the FEI
• improved safety and working conditions for employees
• community welfare

In addition to the opportunities, customer co-creation also entails considerable risks. The risks of customer co-creation are presented in Table 10.

Table 10. Risks related to customer co-creation in the front end of innovation (Hanski & Reunanen 2012).

Risks
• additional time and costs
• strategic risks
• loss of know-how to the customer
• dependence on a customer
• dependence on customer's views and personality
• customer mainly a source of incremental innovations
• only a niche market served
• misunderstandings between customers and company
• ownership of ideas
• increased use of materials and energy
• unemployment and social uncertainty

Customer co-creation is an efficient method for increasing the amount of diversified and customer based information in companies. Through increased knowledge about the customer, co-creation enhances the customer relationships, promotes the development of successful products and services, and enables more sustainable practices. However, in the long run, the indirect benefits (e.g. increased competencies and communication) may well be even greater than the new ideas and customer information. Asset management services can be improved through the benefits listed above. (Hanski & Reunanen 2012)

Customer co-creation also includes risks, however, and as Enkel et al. (2005) state, the risks of not integrating customers are greater than the risks of integration. Risks of not integrating the customers include the risks of less market-driven products and services, lack of reference customers, increase in R&D costs and limited innovation capability by neglecting an important source of ideas.

Companies need to carefully and holistically analyse which customer co-creation projects to participate in and how to maximize the possible benefits and simultaneously minimize the risks involved. Factors increasing the benefits and minimizing the risks of customer co-creation include, for instance, senior management commitment, involvement of both technology and marketing departments in the co-creation process, clearly defined responsibilities, learning from past experiences, choosing the “right” customer, reducing the single customer bias and preparing intellectual property agreements (Kausch 2007).

In conclusion, learning new solutions requires a combination of knowledge from several different sources (Rollins et al. 2011). Even though customer co-creation and customer observation are very usable methods for identifying customer needs and bringing new ideas into the innovation process, companies also need other source§s of information.

4. Portfolio management

4.1 Business model perspective

The business model is a crucial part of a product-service system. It is a useful framework during the early phases of idea generation, concept development and can serve as a good checklist during further development phases.

An example of a method capable of providing a business model perspective on PSS development is the Business Model Canvas by Osterwalder & Pigneur (2009). This offers a holistic perspective on the generation of solutions for customers (Osterwalder & Pigneur 2009) and can also be applied to the comparison of different business models. The business model canvas is presented in Figure 8.

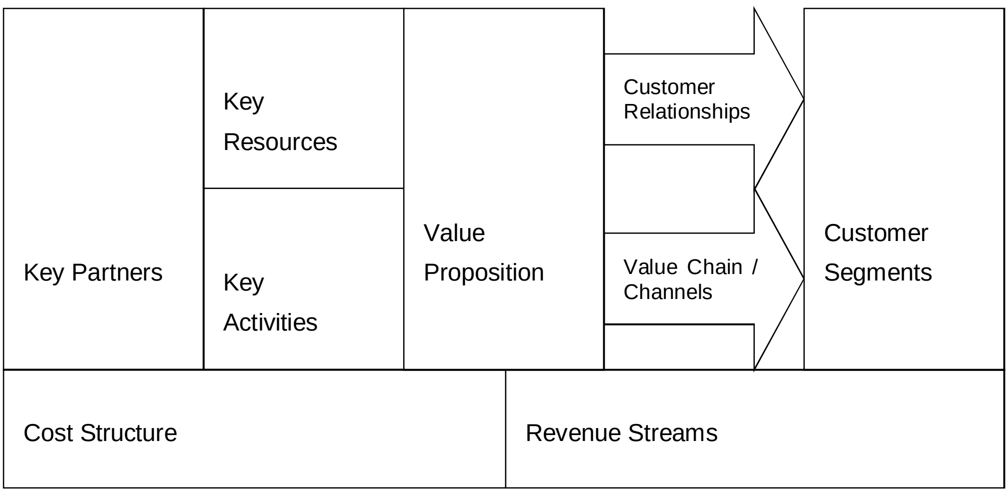

Figure 8. Elements of the Business Model Canvas (adapted from Osterwalder & Pigneur 2009).

The customer segments building block defines the organisations a company wishes to reach and serve. It answers the important questions of “for whom are we creating value” and “who are our most important customers”. The value propositions building block describes the content of the product-service system which aims at creating value for a specific customer segment. Values may be, for instance, newness, performance, customisation, design, price, reduction of costs and risks, accessibility or usability. (Osterwalder & Pigneur 2009, pp. 20–25)

Channels are the customer interface and describe how a company delivers the value proposition to its customer segments. The channels building block includes communication, distribution and sales channel. The customer relationships building block describes which type of relationship a company establishes with specific customer segments. Possible relationship types include personal assistance, self-service, automated services, communities and co-creation. (Osterwalder & Pigneur 2009, pp. 26–29)

Revenue streams represent the generated cash flow from each customer segments. There are several ways to generate revenue, for example, asset sale, usage and subscription fee, lending, renting, leasing, licensing and advertising. Pricing mechanisms also have a considerable effect on the revenue streams. The two main types of pricing mechanisms are fixed (predefined prices) and dynamic (market conditions affect the prices) pricing. (Osterwalder & Pigneur 2009, pp. 30–33)

Key resources represent the most crucial assets for the success of the business model. The key resources can be categorised into physical, intellectual, human and financial resources. Other important building blocks for the success of the business model are the key activities; key activities represent the most important things a company must do to be successful. These crucial activities differ from company to company but can be roughly divided into three main categories: production (activities related to designing, making and delivering a product/service), problem solving (knowledge management and training) and platform/network (service provisioning as well as platform management and promotion of great importance). (Osterwalder & Pigneur 2009, pp. 34–37)

The key partnerships building block describes the network of partners and suppliers which enables the success of a company. The main motivations for creating partnerships are optimisation and economies of scale, reduction of risk and uncertainty, and acquisition of particular resources and activities. Different types of partnerships can be distinguished as follows: strategic alliances between competitors (coopetition) and non-competitors, joint ventures and buyer-supplier relationship (assuring reliable supplies). (Osterwalder & Pigneur 2009, pp. 38–39)

The last building block is cost structure and describes all costs incurred when operating a business model. Cost structures may be divided into two classes: cost-driven and value-driven. Usually the business models have elements from both these extreme cases. Cost structure may include the following characteristics: fixed costs, variable costs, economies of scope and economies of scale. (Osterwalder & Pigneur 2009, pp. 40–41)

The practical application of the method is feasible with A4-sized papers, posters and post-its or smart boards when available. The method supports both individual and group work. In addition to having a well thought-out business model, PSS also need to be aligned with the strategy of the company.

4.2 Aligning PSS with the strategy

PSS development could be seen as a potential strategic investment aimed at developing the company's current business portfolio and narrowing current and future gaps related to corporate strategy requirements and objectives (Seider 2006). The corporate strategy – and embedded within it the innovation, asset, maintenance and other functional strategies - must drive the projects in which the company ultimately invests. (Cooper et al. 2001) The corporate strategy is, in essence, a top-down process in which visioning leads directly to decisions on products, services, processes and operations. Functional strategies (e.g., regarding innovations and assets) should clarify how the function in question supports the achievement of the desired competitive advantage and the goals defined in the company strategy. Different functions should be involved in drawing up the corporate strategy in order to ensure that the planned investments in PSS are fully aligned with it. Structured dialogue and the exchange of knowledge with different functions should be maintained during the planning process. (Killen et al. 2008)

Companies also have to find a balance between using their existing strategies to assess product-service portfolios and using new sets of products and services to redefine their strategies. Taking the existing strategy as given and using it to shape the portfolio is often referred to as the top-down approach, whereas using new products and services to redefine a strategy represents the bottom-up approach (Figure 9). Empirical studies have shown that a more participative strategy formulation process incorporating both top-down and bottom-up elements improves the integration of strategic and operative management. (Poskela et al. 2005, Terwiesch & Ulrich 2008)

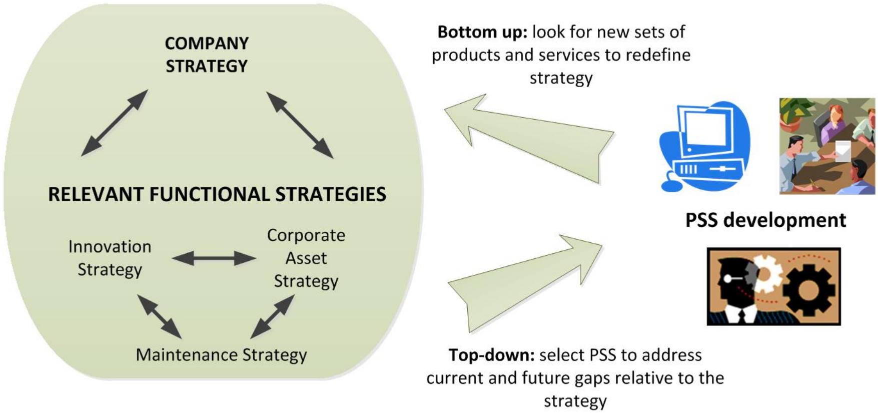

Figure 9. Top-down and bottom-up approaches to managing PSS development.

Building a clear and realistic plan of action for transforming a PSS development into a successful set of products and services calls for clear choices concerning where the business will compete and why it will succeed. It needs an unambiguous explanation of why this strategy will create superior value for the customer and capture sustainable value for the company. (Castellion 2006, Hassett et al. 2011) Several broad objectives support efforts to achieve strategic alignment in this process (Cooper et al. 2001):

- Strategic fit is the first and easiest objective to formulate. Are all product-service portfolios consistent with the strategy? For example, if certain technologies or markets have been defined as key areas on which to focus, do the portfolios fit into them? Is there a need to redefine the strategy?

- *Strategic contribution* is more complex and subtle. Which new PSS projects should be implemented in order to realise the strategy and achieve the goals? For example, if the new product / service targets a new market segment, what projects should be undertaken in order to ensure success?

- *Strategic priorities* focus on spending. Are they reflected in the breakdown? If the company is in a growth business, then the majority of R&D spending should be on PSS projects that are designed to foster growth. In short, does the total number of areas in which the company is spending money reflect the strategy? The answer is often ‘No’.

The strategy view is also the key element in portfolio management. Portfolios in the context of PSS could be defined as a group of products and services being explored under the management of a particular company. A number of isolated products or services do not constitute a portfolio, however – they simply consume time and resources. The main factors distinguishing the management of multiple projects from portfolio management concern the purpose and the planning horizon. The purpose of portfolio management is to select and prioritise the set of products and services, whereas in the case of multiple projects it is merely to allocate resources. Furthermore, portfolio management focuses on strategic decisions whereas multiple project management is more concerned with tactical and operational decisions. (Dye & Pennypacker 1999, Archer & Ghasemzadeh 1999)

4.3 Product-service portfolio management

In general, portfolio management can be described as a dynamic decision process (Dayananda et al. 2002). There are numerous portfolio management concepts, such as project portfolio management, financial portfolio management, product portfolio management and IT portfolio management. Typically portfolio management is associated with either financial assets, such as stocks and bonds (financial portfolio management, FPM), or project portfolio management (PPM) which ensures that the set of projects chosen and completed meets the goals of the company (Kendall & Rollins 2003). Another area in which companies have moved toward a portfolio management approach is information technology (IT portfolio management). Examples of IT portfolios would be planned initiatives, projects and ongoing IT services (such as application support) (Varghese 2008). In any PSS development, portfolio management is very useful in selecting a portfolio for the proposed new products or service and in maximizing the portfolio value or the profitability (Kendall & Rollins 2003). In an ideal world the portfolio should be inclusive of all investments: people, product, services, processes, technology and software. However, a company's focus on capital expenditure often takes necessary attention away from operative expenditure. By adopting a narrow view of which products and services are worth optimising, many companies are missing out on a considerable opportunity to improve performance and accountability (Sanwal & Crittenden 2007). In general, regardless of the managerial approach, portfolio management is the science of making decisions about investment mix and policy, matching investments to objectives, asset allocation for individuals and institutions, and balancing risk against performance (Dayananda et al. 2002, Kendall & Rollins 2003, Sanwal & Crittenden 2007).

How, then, can portfolio management in the context of PSS help companies? For one thing, it strengthens the company's overall ability to manage its portfolio of products and services and thus contributes to its success. It could also be described as a dynamic decision process involving the constant revision of current and new products and services, potential and current R&D projects, and other initiatives. All product-service portfolios should be evaluated, selected and prioritised, and not only in terms of money, but also with regard to management time and other human-resource aspects. This process encompasses or overlaps with a number of decision-making processes within the business, including periodic reviews of the total project portfolio, making go/kill decisions on individual projects and developing new strategies, and resource allocation among business units. As the framework in Figure 10 illustrates, the inputs include product-service portfolios initiated either internally or externally, the boundaries include resources such as time, money and people, the objectives are derived from the corporate mission, vision and intent, and the output is a portfolio of managed and funded projects. (Cooper et al. 2001, Levine 2005, Sanwal 2007) Assessing the value of product-service portfolio can be considered a continuing process. There are feedback loops at different stages. The feedback from evaluation to strategic planning plays an important role in the overall capital budgeting process.

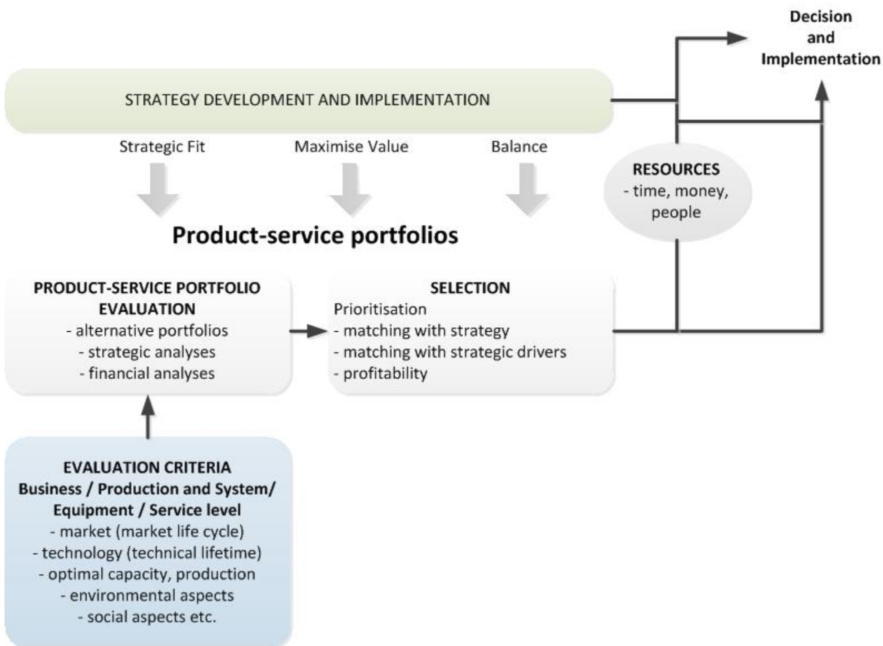

Figure 10. A portfolio framework for PSS.

A product-service portfolio should be managed in a similar way to a financial portfolio; riskier strategic investments (high-growth stocks) are balanced with more conservative investments (cash funds), and the mix is constantly monitored to assess which projects are on track, which need assistance, and which projects should end (Dayananda et al. 2002 Sanwal & Crittenden 2007). Consequently, products and services comprising low or medium uncertainty are mainly focused on creating a portfolio of maximum financial value, whereas high-uncertainty opportunities are pursued in order to strengthen the company's future position or hedge against changes in the market. There are also interdependencies among the products and services, which need to be factored in so as to avoid market cannibalisation and the use of the same scarce resources. Sensitivity to these interdependencies means keeping an eye on the value of the entire portfolio of products and services as opposed to jumping in too quickly when some of them appear financially attractive in isolation. (Terwiesch & Ulrich 2008) Companies should consider products and services in familiar areas, but also explore new territory and thereby create options for future strategic moves.

Any comprehensive portfolio approach should include the following generalized processes: project selection, project prioritisation / re-prioritisation, portfolio monitoring, portfolio assessment, corrective action management and project termination and removal (Ciliberti 2009). In Kendall's & Rollins' view (2003) portfolio management has six major responsibilities:

1. Determining a viable investment mix, one that is capable of meeting the goals of the company
2. Balancing the portfolio to ensure a mix of investments that balances short term vs. long term, risk vs. reward, research vs. development etc.
3. Monitoring the planning and execution of chosen investments
4. Analysing portfolio performance and ways to improve it
5. Evaluating new products and services against the current portfolio and comparatively against each other
6. Providing information and recommendations to decision-makers at all levels.

In the literature, models of the portfolio management process usually have four distinct stages: 1) strategic considerations, 2) individual project/investment evaluation, 3) portfolio selection, and 4) stage/gate evaluation (Sanwal & Crittenden 2007, Archer & Ghasemzadeh 1999, Bridges 1999, Nelson et al. 1997, Radosevich & Hayes 1973) in the following, the investment portfolio evaluation phase is discussed in more detail.

4.4 Evaluation of product-service portfolios

Various aspects should be taken into account in the evaluation of product-service portfolios. It should cover both quantitative and qualitative factors and also include the assessment of uncertainties. Methods for evaluating for portfolios fall into different categories including financial assessment, alignment with the business strategy, scoring models and checklists. (Cooper et al. 2001, see also Figure 11) According to Cooper et al (2001, II), financial assessment is the most popular method in companies, and strategic approaches are also quite widely used. Whatever the method, it should be easy to understand and implement, and transparent. Decision-makers should also understand the key assumptions behind the evaluation, how the analysis and calculations were carried out, and what the final results really mean. It is also worth noting that no method will work for everyone, and that a variety of approaches should be used when assessing or comparing product-service portfolios. (Hassett et al. 2011)

Decision Analysis - Multi-attribute value theory / Multi-Attribute - AHP - Benefit theory/Decision trees - Quantitative risk analysis - Models for stochastic dominance (FSD, SSD, TSD) - Models for information value - Markov models - Multi-goal optimisation, simulation etc.	Strategic Approaches, Scoring Models and Checklists - Risk and opportunity analysis - Scenario analysis - Market analysis - Competitor analysis - SWOT analysis - Balanced scorecard - Decision panels - Value trees - Weak signals - Market and technology foresight in general (see also above-mentioned methods) - Checklists - Scoring Models - etc.
Data Analysis - Time series (e.g. ARIMA) - Variance analysis (e.g. ANOVA) etc.	Economic Quantitative Methods - Traditional investment analysis methods: NPV, IRR, ROI, LCC/LCP - Real Option theory - Competition theory models - Game theory models - Demand/supply models, benefit theory - Cost-benefit analysis etc.

Figure 11. Methods and techniques to support evaluation of product-service portfolios (see e.g. Cooper et al. 2001, Sanwal 2007, Bradley 2007, Phaal et al. 2004, Shil & Allada 2007, Proctor & Canada 1992, Kettunen 2009, Koivisto et al. 2009, Koppinen & Rosqvist 2007, Kaplan & Norton 1992).

Although over the decades the literature has described many of the above mentioned approaches to portfolio management, there is still very little evidence of how these techniques work in practice. (Cooper et al. 2001) In addition, many analytical models are often considered too theoretical and complicated for use in companies. It is not surprising that companies continue to flounder here. This is also why most companies do not usually have systematic methods, structures or processes, or even the software, for evaluating portfolios. Consequently, many managers still favour intuition and visions rather than structured and well-tooled analysis. This may be dangerously unreliable when it comes to solving complex, strategic PSS-related problems, for example. Used wisely, however, methods and tools are of help to companies making decisions related to PSS. (Hassett et al. 2011)

4.4.1 Strategy based method for the evaluation of PSS portfolios

Our example of PSS evaluation is a semi-quantitative approach for selecting an optimum portfolio of product-service portfolios, to be applied primarily during the early phases of the PSS development and to integrate the strategic viewpoint to the portfolio evaluation. It consists of structuring hierarchies for different criteria to evaluate PSS, pairwise comparison and determination of the weights of components of the hierarchies and synthesis to reach overall ranking scores for different alternatives. Examples include situations in which many product-service portfolios need to be compared and their strategic fit ensured.

The initial criteria for assessing product-service portfolios represent a combination of the opinions and knowledge of the project case companies, the results of the literature review and the researchers' own knowledge and experience. Figure 12 below lists these criteria. In addition to the top level, 'Portfolio Management", there are three more levels. The main criteria (Level 2) are the following:

1. **Strategy.** A company's strategic fit is the degree to which the PSS in question is congruent with the company's strategy and the degree of strategic importance.

2. **Competitive advantage of solution (PSS).** Synergies within the company. Value proposition to customers: newness, alignment with customer needs, value for money, communicating the value proposition to customers (suppliers, customers, channels, stakeholders e.g. Osterwalder & Pigneur (2009)).

3. **Market Attractiveness.** Determination of the profit potential in a given market or industry (size of markets, growth, margins and pricing, market dynamics, competition situation etc.).

4. **Feasibility of solution (PSS).** Product perspective: technical gap in the solution, technical complexity in the solution, technical uncertainty in the solution. Service perspective: reliability of the solution, availability of the solution, maintainability of the solution, supportability of the solution.

5. **Sustainable company.** Economic effects: estimated profitability (magnitude, e.g. NPV). Environmental effects: reduced material usage, reduced emissions, Social effects: employment, equality).

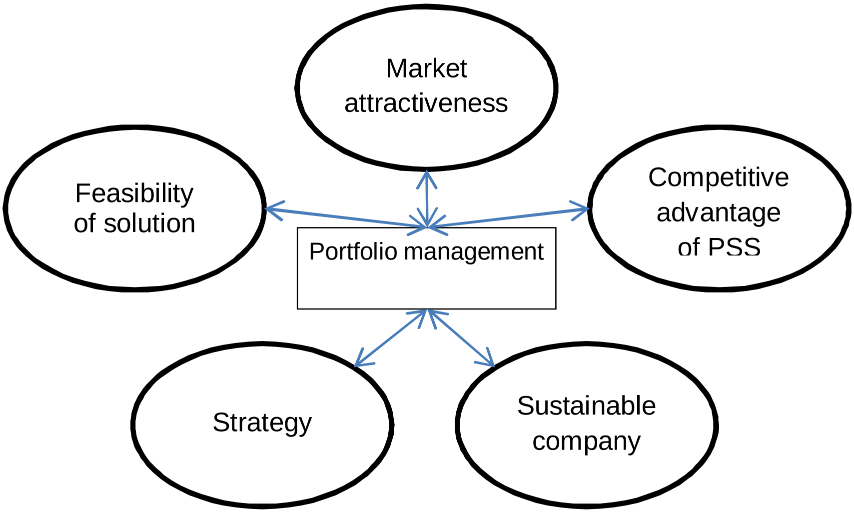

Figure 12. Main evaluation criteria for PSS portfolio management.

As described above, each main criterion is divided into several sub-criteria. The criteria and sub-criteria are typically fixed, but the weights and scores are given during the evaluation. When applying the methods, the next step is to weight and evaluate the criteria and sub-criteria in accordance with expert judgements. Most of the impact scales, in other words the sub-criteria scores, are on five levels: "very high (5)", "high (4)", "medium (3)", "low (2)" and "very low (1)". Multiplying the weights and the impacts gives the profile of PSS alternatives. It is possible to calculate the weighted score for each individual PSS and to rank the different alternatives. The results can be presented in the form of tables or graphs, for example. Having ranked the evaluated product-service portfolios, the order of superiority has been tentatively determined. To conclude, the method described above provides a structure for the inclusion of strategic considerations by linking product service portfolios and the business strategy. (Hassett et al. 2011)

4.5 Value assessment

The identification of the value elements of a service is a task of great importance for both the customer and provider of the solution or service. This is due to the fact that the decision on buying or providing the service or solution should be justified preferably in economic terms. In this chapter, two complementary methods for the assessment of customer value and its elements are presented. These are qualitative Service Quality Function Deployment (SQFD) and quantitative Service Business Value Assessment (SBVA). (Ojanen et al. 2011)

The parallel and combined use of both these methods has two major benefits. Firstly, it provides common practices for the assessment of service value and for the consideration of the particular features in customer's businesses, and provides argumentation on the practical benefits of services. Secondly, value creation should be taken into account at an early phase of productizing (and also product development) and the SBVA process plays a role in this development.

4.5.1 Service Quality Function Deployment

The service quality function deployment is based on the well-known Quality Function Deployment (QFD). The aim of the method is to provide an analysis of how the individual service portfolio elements fulfil the existing customer needs. It is also possible to combine existing services to develop potential new services. By analysing the service features and customer needs, the value elements of the services and the value creation mechanisms are highlighted, which serves as a basis for the assessing of the monetary value of the service. (Ojanen et al. 2011)

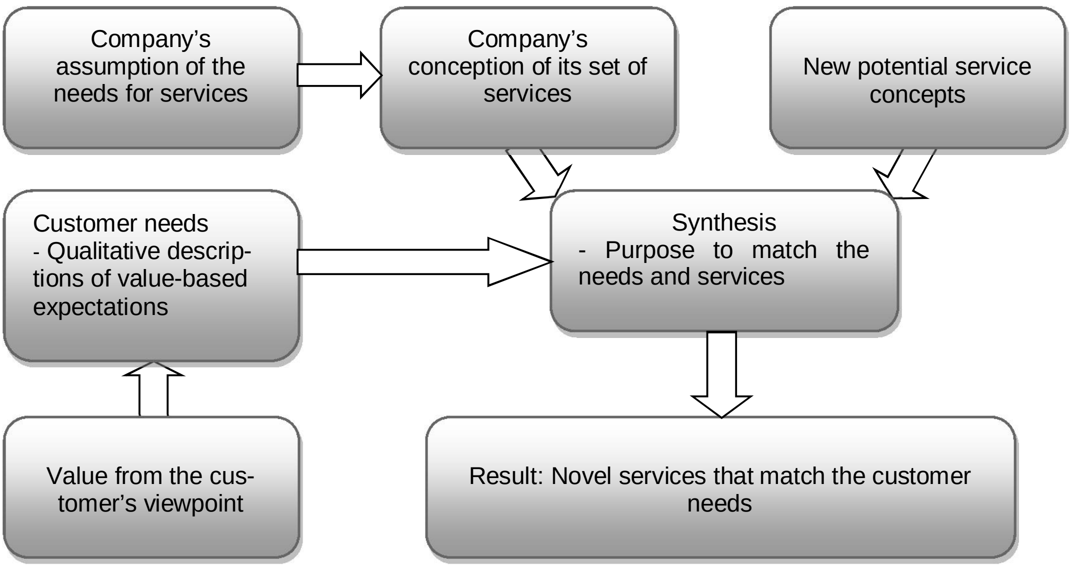

Figure 13. The SQFD process (Ojanen et al. 2011).

The SQFD process is presented in Figure 13. The following phases are included in the process:

- Description of customer needs and their background
- Prioritisation of customer needs
- Gathering a portfolio of existing and potential services

  - o preliminary titles for the services
  - o more specific descriptions for the services (features)
- Analysis of the links between services and customer needs
  - o estimate of the strength of the link (weak-medium-strong)
  - o how the service is correlated with specific customer needs
- Discussion on the correlations between the services
- Evaluation of the results. (Ojanen et al. 2011)

SQFD provides a coherent view of the service portfolio and a list of potential services. It helps to understand what kind of features are present in the potential and existing services and "how the services correlate with customers' expectations". (Ojanen et al. 2011)

4.5.2 Service Business Value Assessment

Quantitative Service Business Value Assessment is presented Figure 14. The detailed process includes "analysis of the customer's business scenarios from the perspective of the key cost factors identified". Thereafter, the business processes related challenges and the most significant failure modes which are related to the technical systems, as well as cost impacts of the services are analysed. At the end, the results of the previous stages are analysed.

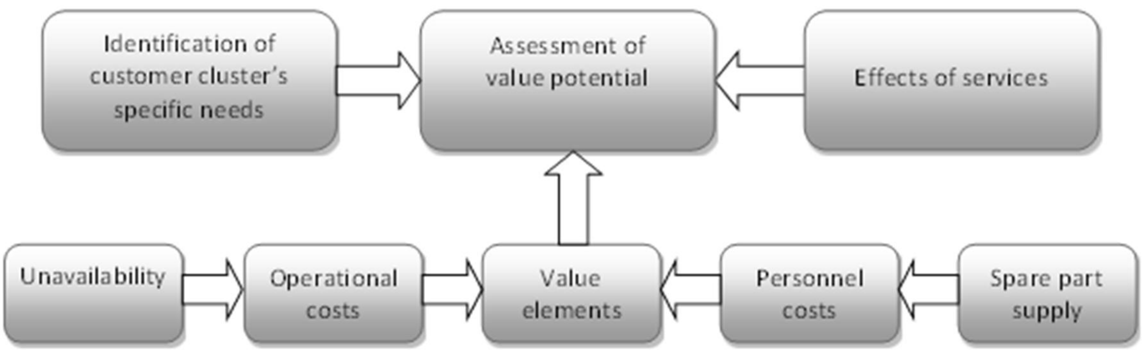

Figure 14. The SBVA process (Ojanen et al. 2011).

SBVA can be used to ascertain the value of the service from a customer's perspective, when the target price is known. Thus, what is evaluated is whether the savings are greater than costs when adopting the service. SBVA can also be used to estimate the real customer value, which supports the service pricing activity. When the assessment indicates a lack customer value in a certain category, the service portfolio can be extended. (Ojanen et al. 2011)

5. Life cycle data / Management of life cycle data (KIBS)

This chapter presents different issues related to data collection in general. Figure 1 presents an overview of the outcomes of the MaintenanceKIBS project. This chapter considers the feedback arrow from the use phase to R&D processes where the information used should be more structural than data used in the innovation phase.

Here the focus is on RAMS data on reliability, availability, maintainability and safety. RAMS data is produced during the whole life cycle of the item in question. This data can be utilised to support many kinds of decisions different actors need to make during the life cycle of an item. Collecting proper data and analysing it needs time, resources and knowledge which end-users nowadays typically do not have. This is one opportunity for manufacturers to collect data and provide services for decision support.

This report makes no distinction between data collected for service development or to develop own production. Basically the requirements for data collection are the same. When a manufacturer wants to move to service business and especially to knowledge-intensive service business one task is to define the data management processes needed to provide intended services.

This chapter first introduces the phases of a life cycle and how production systems typically consist of several hierarchical levels which all have a life cycle of their own. It also discusses the quality of the database and data types to be collected. One aspect in data collection is also data producing and sharing. Especially in the phases preceding operation there are several actors producing data. In the operation phase there are fewer data producers but many actors could utilise data from the operation phase.

5.1 Life cycle of an item

A life cycle is a series of stages through which an item goes from its conception to its final disposal (EN 13306, 2010). The life cycle of an item can be divided in several ways. The roughest division is into three phases; the beginning, middle and end of the life cycle. A more detailed division into six phases is given in the EN 60300 series of dependability standards (SFS-EN-60300-2, 2004):

1. Concept and definition phase
2. Design and development phase
3. Manufacturing phase
4. Installation phase
5. Operation and maintenance phase
6. Disposal phase

Each of these stages can be subdivided into more detailed phases according to the focus. When considering the life cycle from the data collection point of view the operational and maintenance phase can be divided into three parts. The beginning of the operation phase is typically a warranty period when manufacturers are responsible for failures and thus obtain information on every failure. After the warranty period the data typically remains in the end-users' databases and the amount of data the manufacturers get is much less. During the operation period of large systems one or few renewals are typically carried out when lot of data about equipment changes should be produced.

An item is defined as a part, component, device, subsystem, functional unit, equipment or system that can be individually described and considered (EN 13306, 2010). A large production system is deemed to be built up on several different systems consisting of different sub-systems, and sub-systems are built up from several components. All these items have a life cycle of their own (Figure 15).

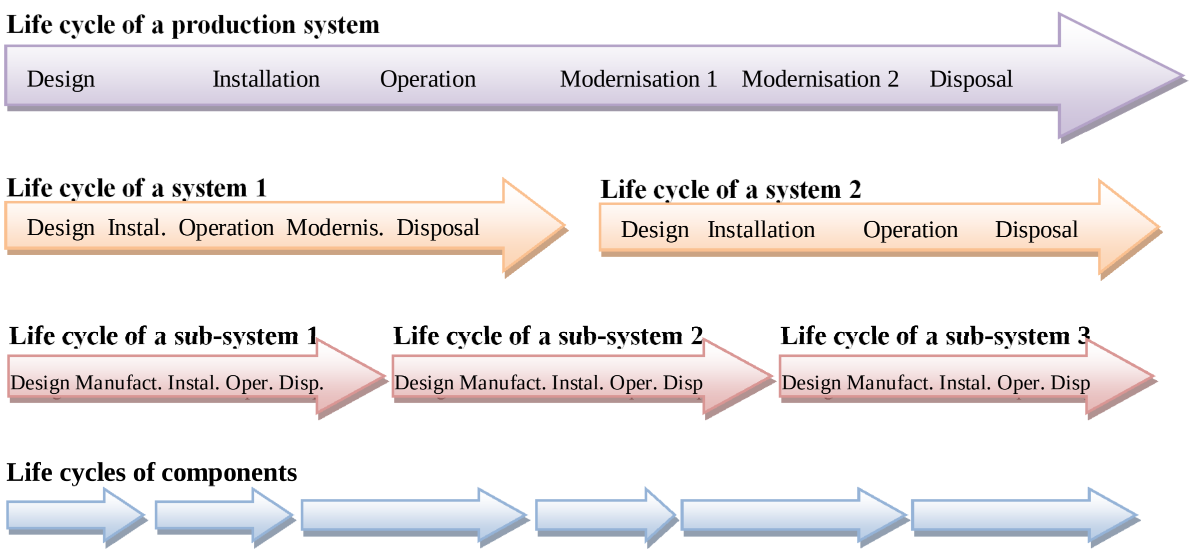

Figure 15. Hierarchy of life cycles.

When considering these life cycles from the perspective of data management, it can be concluded that relevant data should be collected at all levels and lower level data should be available at higher levels. Relevant data types at different levels and life cycle phases are introduced in Chapter 5.3 and the actors involved at different levels and life cycle phases will be presented in Chapter 5.4.

5.2 Utilisation of life cycle data

According to the SFS-EN 60300-3-2 standard (2005) failure and usage data enable:

- maintenance planning
- justification of modifications
- calculation of future resource and spares requirements
- confirmation of contractual satisfaction
- assessment of likelihood of achieving a successful mission
- feedback to design and manufacturing
- estimation of cost of warranty period
- improve dependability requirements
- collection of basic data for possible liability cases
- collection of usage data to determine field customer requirements which provide the basis for supplier dependability test specifications and demonstration programmes.

As the previous list shows, data produced during the life cycle of a product can support various decision situations during the life cycle of the item itself or during the life cycles of next version items. Decisions can relate to the development of the structure of an item, component selection for a system, maintenance service development i.e. when defining optimal maintenance policy or maintenance period, allocation of investment budget, definition of warranty time or availability performance, management of spare parts etc.

Product-service providers can collect data to support their own decisions related to their services and products. Another option is to collect data and support their clients' decisions as a service.

5.3 Content of life cycle data

Generally life cycle data can be divided into two classes; static data and dynamic data. Static data usually includes information about materials used, components, suppliers, assembly options and use instructions. This kind of data is typically produced before the operation phase. Dynamic data includes, for example, the use and maintenance data of an item.

SFS-EN 60300-3-2 (2005) standard classifies dependability data into four classes; inventory, usage, environment and events. Inventory data is static data identifying the manufacturer, batch number, modification state, repair history etc. Inventory data is important e.g. to identify failed item which enables the following of trends in databases. Usage data describes what functions, how often and how long the item in question has performed. Environment data includes information about the normal use environment but also about the damage and environmental stresses the item has suffered. Environment data reveals the real use conditions and thus provides important data for specifying test requirements. Failures and maintenance actions are the most important events in event data. The next chapter describes data types in more detail.

5.3.1 Quality of data

The first task when starting data collection is to define the means to ensure the quality of the future database. The main requirements for useful data are sufficient quality and sufficient number of observations. Data quality consists of several different aspects. For example, Kahn et al. (2002) have listed 16 different dimensions of information quality (Table 11).

Table 11. Dimensions of information quality (Kahn et al. 2002).

Dimensions	**Definitions**
Accessibility	the extent to which information is available, or easily and quickly retrievable
Appropriate Amount of Information	the extent to which the volume of information is appropriate for the task at hand
Believability	the extent to which information is regarded as true and credible
Completeness	the extent to which information is not missing and is of sufficient breadth and depth for the task at hand
Concise Representation	the extent to which information is presented in the same format
Ease of Manipulation	the extent to which information is easy to manipulate and apply to different tasks
Free-of-error	the extent to which information is correct and reliable
Interpretability	the extent to which information is in appropriate languages, symbols and units and the definitions are clear
Objectivity	the extent to which information is unbiased, unprejudiced an impartial
Relevancy	the extent to which information is applicable and helpful for the task at hand
Reputation	the extent to which information is highly regarded in terms of its source of content
Security	the extent to which access to information is restricted appropriately to maintain its security

Timeliness	the extent to which the information is sufficiently up-to-date for the task at hand
Understandability	the extent to which information is easily comprehended
Value-Added	the extent to which information is beneficial and provides advantages from its use

The previous table presents a long list of aspects to consider when planning data collection. The importance of these varies in different cases but they all still need to be considered when making the decision on relevancy for the case at hand. The list above points out two issues important in data collection. Firstly, it needs planning and resources to be able to collect data of good quality. Secondly, data quality is assessed through the task it is collected for. Thus, there is no quality of data before the task is defined. Tasks can be formulated as questions to be answered by the data collected, i.e. what is the lifetime of a component or does the lifetime vary according to the use environment.

A simple example reveals a connection between data quality and task definition. Table 12 presents an example of fairly typical failure data collected from a production system. From this table itself it is not possible to say whether this data is good or not. If it is known that the task is to recognise sub-systems causing most failures it is easier to assess data quality. When considering the table above with quality dimensions it can be seen that through the data itself without any background information is it possible to assess only its relevance. Of course relevancy is one of the key issues, if the data is not relevant it cannot have great value even if other quality dimensions are in order. The relevance of the data is in order if the task is to recognise sub-systems causing the greatest number of failures because the sub-system can be identified by its item code.

The case would be different if the task were to recognise the most critical subsystems. Usually the correlation between number of failures and criticality is not straightforward. Criticality also consists of the magnitude of the consequences. Data relevance in this case depends on the meaning of start and finish times. Is the time between start and finish stoppage time or maintenance time? Or are these merely time stamps from the system without real connections to production or maintenance?

Assessing other aspects of the data quality requires background information. For example to evaluate the completeness of the data it is important to know the data collection practises, like are all failures recorded etc.

Table 12. Example data.

Failure date	**Start time**	**Finish time**	**Failed item**	**Failure description**	**Spare parts used**
10.2.2012	8:15	14:38	JKL-008_34	Broken	SP-0056
10.2.2012	13:20	13:40	JKL-07_21	Pump changed	SP-0012
11.2.2012	10:45	12:12	JKL-001_34	Valve leaks	SP-097
…					

5.3.2 Data types

In the preceding chapter it was argued that data to be collected needs to be defined according the task in hand. Thus it is impossible to give a comprehensive list of variables needed in all manufacturing companies. However, it is possible to find some typical tasks for manufacturing companies. Those tasks are discussed in Chapter 5.2. According those tasks it is possible to find data types typically useful in manufacturing companies. Data types are not specific variables but issues for which it might be useful to define variables to be collected. Table 13 below presents data types produced in different life cycle phases of a component. These can be used as a reference when starting the definition of actual variables for defined tasks.

Table 13. Data types produced for component level items.

Design	**Manufacturing**	**Installation**	**Warranty period**	**Operation**	**Disposal**
Structure information	Changes in manufacturing plan	Identification data	Warranty costs	Failures	Recycling and disposal of materials and components
Use instructions and restrictions	Sub-contractors	Date of commissioning	Failures during warranty period	Preventive maintenance	Disposal costs
Maintenance programme	Manufacturing costs	Installation costs		Safety related incidents and observations	
Estimate of key performance indicators	Manufacturing history	Assessing of installation work		Changes in maintenance	

Recycling plan				Changes in use position	
Identification data				Failure, maintenance and operation costs	
Design costs				Customer feedback	
Estimate of component life cycle cost				Use environ-ment and load-ings	
Test results					

5.4 Data producers and utilizers

A large production system, e.g. a paper machine, mobile work machine etc., includes numerous different components, subsystems and systems produced by different manufacturers. In other words, the production system used by the end-user is produced by a network of manufacturers. In the operation phase there is also a network of actors supporting the end-user to operate the machine in the appropriate way. Basically there are two networks related to the life cycle of the production system (Figure 16). The target of the first network is to plan and manufacture the production system. The second network operates and supports the operation of a production system.

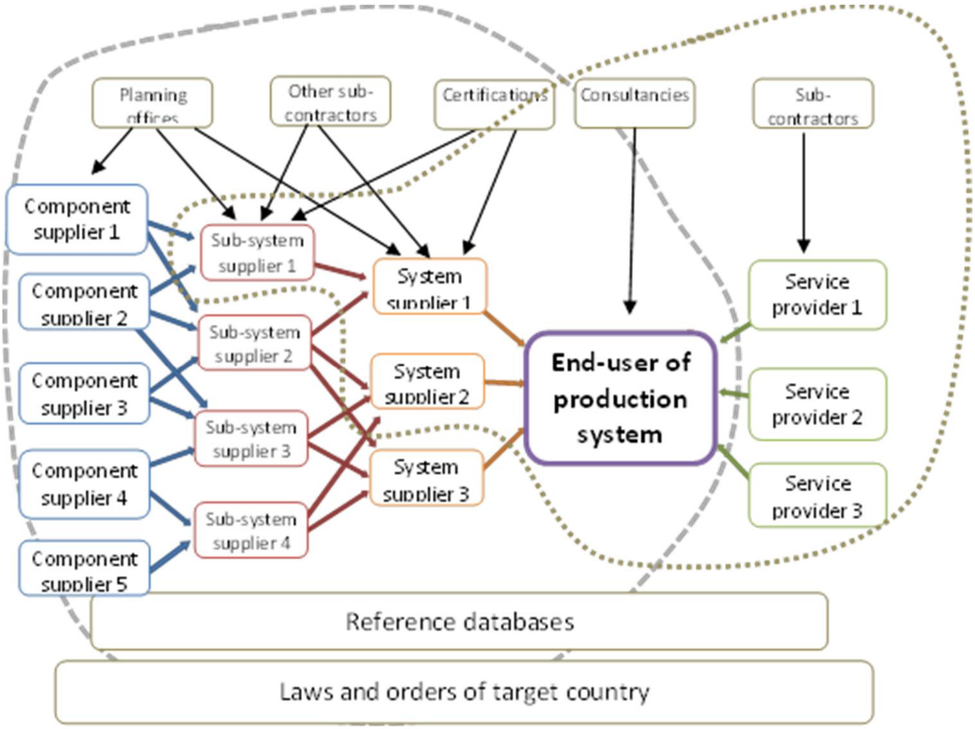

Figure 16. Two networks of actors from the end-user's point of view. (The grey broken line describes the network for before the operation phase and the light green dotted line describes the network for the operation phase.)

From a data collection and utilising perspective these two networks include several actors who produce data and need data. Thus, when collecting data for certain tasks other actors, outside or inside the own organisation, which may have useful data need to be kept in mind. When all the data needed is inside the own organisation situation should be quite simple, it is usually possible to have access to data. The situation is more complicated if another organisation is the owner of the data needed. Then there come practical problems caused by incompatibility between organisations' software. A possibly greater problem is willingness for data exchange. One barrier to data exchange is that data owners do not want to share data which is too close to their core business. Another consideration inhibiting data exchange is that it is considered too expensive, no-one is willing to pay the costs of data exchange.

Nowadays data exchange works quite well in the design and manufacturing phases when different parties are in a contractual relation. Data collected during operation time typically remains in end-user databases. Figure 17 depicts the current situation. Operation time data is very important when developing items and designing new versions.

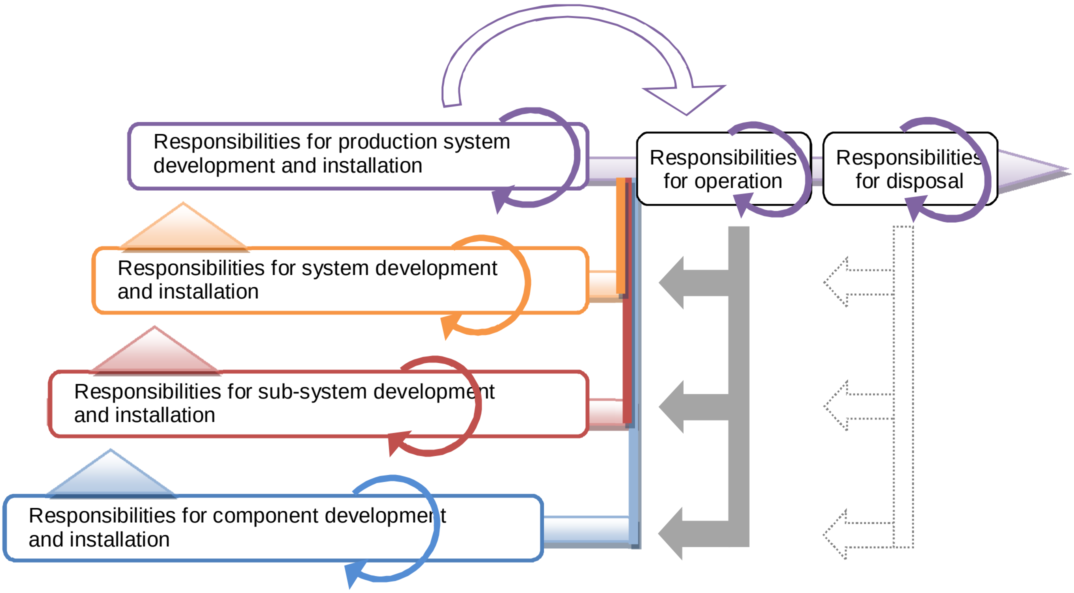

Figure 17. Data producers and utilizers from a data flow perspective.

5.5 RAMS management

As previously noted, RAMS data management has many aspects to be considered. Thus organisations collecting and analysing RAMS data need to define the processes and methods to produce, collect, analyse and utilise data for different life cycle phases. RAMS data includes reliability, availability, maintainability and safety data, in some contexts the role of the component's and system's inspectability is essential and it becomes a question of RAMSI data management (Tiusanen et al. 2011).

The role of RAMS management is most significant during the development phases because this is when the most important decisions concerning availability and safety are taken (Kivipuro et al. 2008). RAMSI requirements are meant to guide the system development process in its different phases. The exploitation of a systematic RAMSI program aims to identify, analyse and assess availability and safety issues and specify requirements in the most appropriate way from the very beginning of the system development project. RAMSI requirement management as an essential part of general systems engineering approach tries to help avoid situations where defects in availability and safety performance go undetected until the system is already operating. Corrective actions are then difficult and expensive to execute. (Tiusanen et al. 2011)

In essence, RAMSI program can be viewed as a documented set of time scheduled activities, resources and events serving to implement the organizational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that a system will satisfy given requirements relevant to a given contract or project. Examples of RAMSI activities related to certain life-cycle phase are shown in the Figure 18**Error! Reference source not found.**. (Tiusanen et al. 2011)

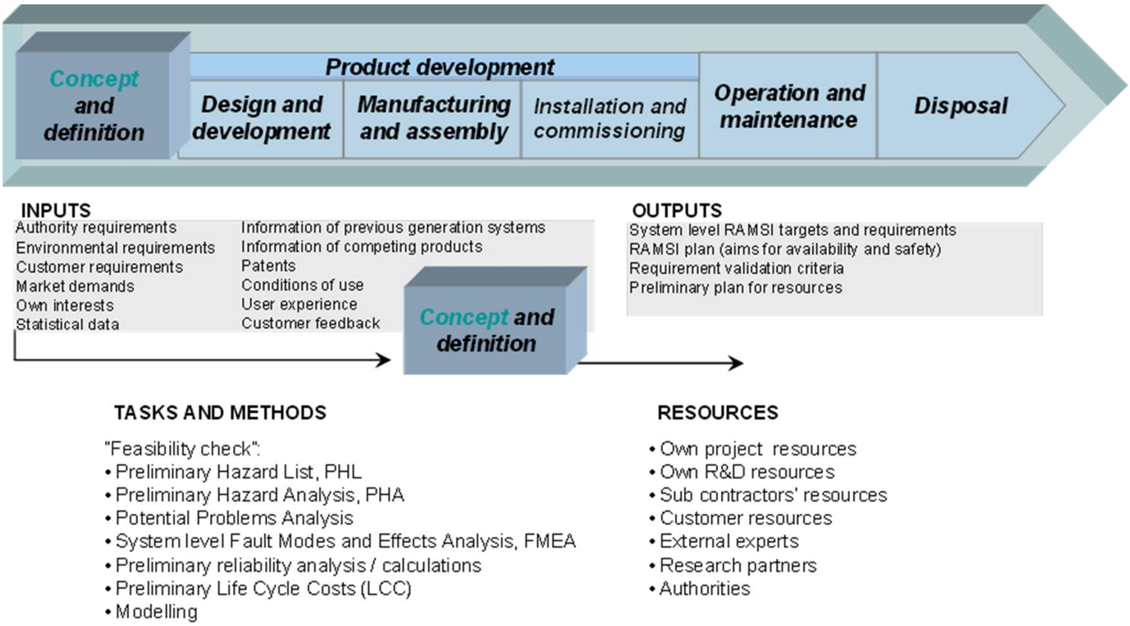

Figure 18. RAMSI activities in the conceptual design phase (Tiusanen et al. 2011).

6. Conclusions and recommendations

In this final chapter we answer the following research questions presented in the introduction:

1. What is the state of the art in PSS development?
2. What kind of knowledge is needed in the first stages of PSS development and how to gain access to this knowledge?
3. How can PSS portfolios be evaluated?
4. Which sources and information needs could be a basis for new knowledge-intensive business services (KIBS)?
5. What kind of PSS development model would be suitable for industrial companies?

To answer the first research question, a literature review and interviews were conducted in Finnish companies. As a conclusion on the state-of-the-art, companies need a more systematic approach to the development of PSS. If systematic product development practices exist in the company, they serve as a good foundation for systematic PSS development processes. The literature review revealed that there are not many systematic approaches to the development of PSS available and none of the methods is commonly used. However, the concept of PSS is strongly supported in academia and several practical PSS applications can be found in the literature (e.g. Tukker 2004). The benefits of PSS are also widely discussed in the literature (see Tables 2 and 3). Taken together, these factors show that there is a need for systematic PSS development processes like those described in this report. Through the literature research it also became evident that the development of a comprehensive and universal PSS development framework would be extremely difficult and even impossible. Instead, we decided to provide the companies with a toolbox (see Figure 19, a duplicate of Figure 1), which offers help in the various stages of the PSS development and the related processes such as the data and knowledge management.

Various kinds of knowledge are needed in the development of product-service systems. The knowledge is especially important in the very first stages of the PSS development processes. The second research question is addressed by identifying the different business and production environment related knowledge types as well as the customer related knowledge types. However, methods for capturing these crucial knowledge types are also needed. To capture especially the customer related knowledge, a customer observation method was created. Other customer related information sources were also contemplated when discussing the opportunities and risks inherent in customer co-creation (integration of the customer into the development processes). The effective and efficient idea and knowledge capturing processes coupled with good idea and knowledge management processes are a competitive advantage for a company. The methods developed and discussed in this report, however, are not enough to achieve comprehensive knowledge and idea capturing processes; more conventional sources of ideas and knowledge (surveys, interviews, customer satisfaction questionnaires, patents, technology reports, market information etc.) are also needed.

The third research question addresses the evaluation (and also management) of PSS portfolios. It discusses the strategic and management issues, as well as the optimization of the different products, services and activities included in the PSS portfolio. To answer the third question, the perspectives of business model and strategy were presented. The decisions on portfolio management are to a great extent connected to the strategy (see top-down and bottom-up strategies in Chapter 4) and affected by the business models of the company. In order to evaluate the profitability, risks and benefits of the portfolios, criteria for the evaluation of the PSS portfolio were created. Other tools for the evaluation of portfolios were also presented. An important and under-researched part of PSS portfolio evaluation is the assessment of the customer perceived value of services. In this report two methods for such assessment were presented; qualitative SQFD and quantitative SBVA (see Chapter 4.5). Portfolio management and evaluation methodologies, especially in the context of PSS development, have not yet been extensively researched. In addition to this, the complexity of PSS is another reason for the need of new PSS portfolio management frameworks.

The fourth question contemplates the possible information sources and needs that could be the bases for new knowledge-intensive business services (KIBS). KIBS are an important and growing part of services, which include, for example, many of the maintenance services provided. Data and data collection are central in the provision of KIBS. To form a holistic view on the sources of and needs for information, a hierarchical life cycle model of information was created. The possible users, benefits, level and quality of the data were addressed comprehensively. As an important factor, the network of actors involved in the delivery of KIBS was also presented. An important perspective related to maintenance-based KIBS is the management of RAMS data. RAMS data guides the complex system development processes and is a potential source of opportunities for KIBS.

Question number five was already partially answered when answering the previous questions. In order to better cater for the needs of the PSS in the development processes, company- and case-specific processes like those presented in Figure 19 (below) should be defined. Systematic product and service development processes are prerequisites for the systematic PSS development processes (Aurich et al. 2004).

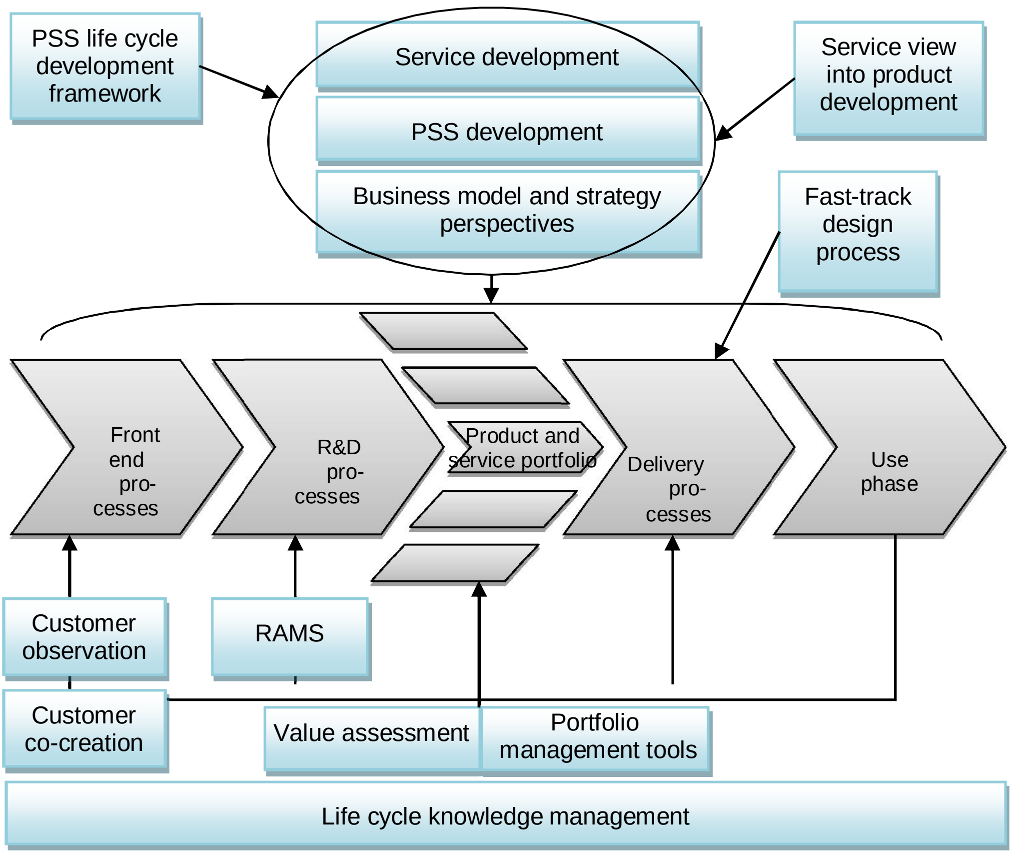

Figure 19. Overview of the outcomes of the MaintenanceKIBS project. Proposed approach, methods and tools (blue boxes) to be applied at the various stages of the product and service life cycle (grey arrows).

Companies should consider comparing the benefits and weaknesses as well as the risks and opportunities of the individual methods presented in Figure 19. The application of a bundle of methods should also be assessed as a whole to be able to decide which combination of methods best serves the needs of the company. The benefits of PSS are comprehensive and companies should contemplate if they could translate these benefits into their businesses.

A considerable amount of research in the areas of KIBS and PSS, however, remains to be done. More research is needed to verify the benefits and risks of PSS development. Some of the methods proposed were tested in practice, but the proposed toolbox as a whole is yet to be piloted. Further research is needed to create models to manage complex PSS portfolios.

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Title	**Development of knowledge-intensive product-service systems** **Outcomes from the MaintenanceKIBS project**
Author(s)	Jyri Hanski, Susanna Kunttu, Minna Räikkönen, Markku Reunanen
Abstract	Many manufacturing companies are considering the opportunities which industrial services can offer them along their core products. The development of services offers the companies new growth opportunities. The growth of technology-based knowledge-intensive business services (KIBS) has been enabled by outsourcing and globalisation, for instance. Moreover, the profitability of services is usually higher than the profitability of the other industrial businesses, and they offer profits throughout the entire life cycle of the product. The development of integrated product-service solutions is not without challenges. Product and service design are typically accomplished separately in different organization units. Technical personnel are responsible for the development of physical products while service planning is made by the marketing organization. Consequently services are generally planned afterwards, causing problems in the compatibility of products and services. Moreover, in many cases too little attention has been paid to the business analysis of product-service systems (PSS), for example, life cycle profit evaluation or revenue logic assessment of alternative product-service systems. In manufacturing companies, the processes related to the development of products are usually systematic, but the service development is intuitive and disconnected from the product development processes. However, the services offered and developed should be compatible with the existing product and service portfolio. Customers increasingly demand solutions from their suppliers that are comprehensive and fulfil the customer needs. The development of product-service design processes enables the companies to design solutions consisting of the best possible combination of products and services from the perspective of the customer and the supplier. The adoption of PSS design helps the companies to take the services into account when developing products and vice versa. With the help of the new PSS design methods the lead-times of the development processes may be shortened, and better quality solutions achieved when the specific characteristics of the products and services can be taken into account as early as possible. The goal of the MaintenanceKIBS project is to develop methods for knowledge-intensive service and product design. For instance, we provide tools and practices for concurrent design of product and service, for managing and utilizing information gathered in different planning phases and for assessing the life cycle costs and profitability of the alternative product-service-concepts.
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Nimeke	**MaintenanceKIBS – Tieto- ja osaamisintensiivinen tuote-palvelusuunnittelu teollisen liiketoiminnan arvoketjussa** **MaintenanceKIBS-projektin loppuraportti**
Tekijä(t)	Jyri Hanski, Susanna Kunttu, Minna Räikkönen, Markku Reunanen
Tiivistelmä	Tuotannollista liiketoimintaa harjoittavat yritykset tarkastelevat yhä useammin mahdollisuuksia, joita teolliset palvelut voivat heille tarjota tuoteliiketoiminnan rinnalla. Palveluiden kehittäminen tarjoaa yrityksille sekä kasvumahdollisuuksia että uudenlaisia ansaintamalleja. Teknologiaperustaisten tieto- ja osaamisintensiivisten palveluiden (KIBS) kasvuun ovat vaikuttaneet mm. palveluiden ulkoistamiskehitys ja kansainvälistyminen. Lisäksi palveluiden kannattavuus on yleensä huomattavasti korkeampi kuin teollisuuden muiden liiketoimintojen, ja ne tarjoavat tuottoa tuotteen elinkaaren kaikissa vaiheissa. Integroitujen tuote-palveluratkaisujen kehittämiseen liittyy kuitenkin haasteita. Tyypillisesti kone- ja laitevalmistajan ydintuotteiden suunnittelusta vastaa tekninen henkilöstö, kun taas palveluiden suunnitteluun osallistuvat yrityksen markkinointi- ja jakelutoiminnot. Tästä johtuen palveluiden ja tuotteiden yhteensopivuudessa on ongelmia ja usein palveluiden räätälöinti tehdään vasta jälkikäteen, kun tuote on jo suunniteltu. Myös tuote-palveluratkaisujen liiketoiminnallinen tarkastelu, esimerkiksi vaihtoehtoisten tuote-palveluratkaisujen elinjaksokustannusten laskenta, kannattavuusarviointi sekä ansaintalogiikan määritys, jää usein liian vähälle huomiolle. Valmistavan teollisuuden yrityksissä tuotekehityksen prosessit ovat yleensä tarkasti määritettyjä, mutta palvelukehitystä tehdään oman toimen ohella, intuitiivisesti ja tuotekehitysprosesseista riippumattomana. Kuitenkin, tarjottavien ja kehitettävien palveluiden tulisi olla aikaisempaan tuote- ja palvelutarjoamaan yhteensopivia. Asiakkaat vaativat yhä enemmän kokonaisvaltaisia ja tarpeitaan tyydyttäviä tuotteista ja palveluista koostuvia ratkaisuja toimittajiltaan. Tuote- ja palvelusuunnittelun kehittäminen auttaa yrityksiä suunnittelemaan ratkaisuja, jotka koostuvat asiakkaan ja tarjoavan yrityksen näkökulmasta parhaasta mahdollisesta tuote-palveluyhdistelmästä. Tuote- ja palvelusuunnittelun omaksumisen avulla otetaan tuotteita kehitettäessä huomioon myös tarjottavat palvelut ja palveluita kehitettäessä otetaan huomioon palveluiden toimittamiseksi tarvittavat tuotteet. Uusien tuote-palvelusuunnittelumenetelmien avulla voidaan päästä lyhyempään suunnittelun läpimenoaikaan ja parempaan ratkaisun laatuun, kun tuotteen ja palveluiden erityispiirteet otetaan huomioon mahdollisimman aikaisessa vaiheessa. MaintenanceKIBS-projekti keskittyy tuote-palveluratkaisujen suunnitteluun. Tutkimuksen osa-alueina ovat tuote-palvelusuunnitteluun soveltuvien menetelmien ja työkalujen kehittäminen, eri tuote-palveluratkaisujen ja -portfolioiden arviointimenetelmät, tietointensiivisten tuote-palveluratkaisujen (KIBS) elinkaaren aikana syntyvän ja tarvittavan tiedon hallinta sekä tuote-palveluratkaisujen tarvitseman palautetiedon keräämiseen soveltuvat menetelmät.
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