Linköping Studies in Science and Technology

Licentiate Thesis No. 1671

Implementing an Integrated Product Service Offering Design Method for Complex Products and Systems

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¹Cover art

The cover of this thesis was chosen to illustrate the meaning of the thesis title. The gears represent the industrial aspects of the thesis, while the number and interconnectivity of the gears show the complexity and systematic aspects. Each gear can influence the other parts, even if they are not directly connected. Some gears are not well designed or connected with the rest, which indicates the need for a design method to make the whole system coherent and integrated. The cover is hand-drawn to emphasize the fact that management knowledge has some artistic features in its nature, which often are gained through experience and not always through reading books and scientific journals.

¹ Bonnie Jean Woolger, the designer of the cover art, describes herself as “an artist who lives and works in Decatur Ga. U.S.A. I studied drawing and printmaking at the Atlanta College of Art. My work is filled with repeating patterns. I find my way into the complex beginning with one or maybe several simple shapes that through layering and repetition build their own new form.”

Abstract

Over the last decade, manufacturing firms have shown increasing interest to shift from selling physical products to providing solutions for customer needs. Several concepts, such as the Integrated Product Service Offering (IPSO), have been developed to support these companies.

This thesis sheds additional light on aspects and consequences of applying the SPIPS (Solution Provider through Integrated Product Service development), an IPSO design method for a Complex Product Systems (CoPS) provider through a case study. The thesis reveals that a CoPS provider could benefit by applying the SPIPS method in terms of improving the environmental performance of CoPS, creating synergy between the SPIPS method and other managerial systems (e.g. Customer Value Management (CVM) and Research & Development (R&D) management) and service-related knowledge integration in the product development process.

The SPIPS method can contribute to the environmental performance of CoPS to a wide extent. In the design phase, the most influential phase, the IPSO design method can provide different options to address the environmental performance of CoPS. In the use phase, with the highest environmental impact, the SPIPS method can facilitate the design of different services which could outperform existing technological solutions for changing physical products in terms of contribution to the environmental performance of CoPS.

Furthermore, the SPIPS method can support CVM through developing analytical trees for customer values. Through evaluating the correlation between design parameters and finding the most important ones, designers can focus on the “hot spot” and managers can assign resources in an effective and efficient way. The customer-centric feature of the IPSO concept can also contribute to CVM in terms of improving the process of evaluating customer value, and by providing customized offerings to meet customer needs.

In addition, based on the SPIPS method a process is developed to prioritize R&D projects with regard to provider value and customer value. Provider value and customer value, which are not always the same, are used as drivers for R&D project prioritization. The value-based Quality Function Deployment (QFD) is used to overcome the difficulty of systematically relating R&D projects with customer value. The value-based QFD improves the process of service-related knowledge integration in the design phase of product development, and provides designers with the opportunity to investigate the total effect of each R&D project on customer value over the product life cycle.

Acknowledgement

This thesis completes my research at Linköping University in collaboration with the anonymous company, during which time I have been fortunate to meet many interesting people. I would like to thank my main supervisor Mattias Lindahl for his professional and sincere help during this time. I appreciate his support, guidance, advice and patience during this thesis work. In addition, I would like to thank Per-Olof Brehmer, the head of IEI - Department of Management and Engineering, for his great support which improved the quality of this thesis. I also highly appreciate the contribution of my co-supervisor Tomohiko Sakao to this thesis.

I would also like to thank my colleagues at the Division of Environmental Technology and Management, especially the PhD candidate group, of which a few deserve special mention. Nisse: without you, staying far away from my family would be hard to tolerate. Thanks for the times you hosted me at your home and the nice walks in the forest around Linköping with your son, Mio. Roozbeh and Wisdom: thanks for making our office unique through your kindness and friendship.

I owe a debt of gratitude to the employees of the company who shared their information, knowledge and experiences with me. I would like to especially say thank you to the owner of the project at the company, as well as the service R&D managers and employees of the Business Development Department.

I extend a deep sense of gratitude to my friend Tahmasb Azad, who always has supported me with his knowledge and experiences.

My special appreciation goes to Bonnie Jean Woolger, the artist from Decatur Ga. U.S.A., who generously let me to use her drawing as the cover art of this thesis. Furthermore, I would like to thank Mica Comstock for his time and effort checking the language of this thesis.

Last, but definitely not least, my greatest thanks go to my family, who supported me with their constant love during this time.

List of appended papers

- I. Sakao, T., Taabodi, A., (Submitted). Customer-oriented Method to Design Services: Empirical Studies with Two Investment-machine Manufacturers, in: Larsson, T., Larsson, A., Törlind, P., Isaksson, O. (Eds.), Functional Product Innovation: An Engineering Perspective on Product/Service Systems. Springer.
- II. Taabodi, A., Sakao, T., 2011. Integrating PSS Design Methods with Systems for Customer Value Management and Customer Satisfaction Management, in: Hesselbach, J., Herrmann, C. (Eds.), 3rd CIRP International Conference on IPS2 - Functional Thinking for Value Creation. Springer, Heidelberg, pp. 99–104. ISBN: 978-3-642-19688-1
- III. Taabodi, A., Sakao, T., Lindahl, M., 2014. Incorporation of Product/Service System Concept in R&D for Complex Products and Systems, in: Mochimaru, M., Ueda, K., Takenaka, T. (Eds.), Serviceology for Services: Selected Papers of the 1st International Conference of Serviceology, 2014. Springer, New York, in print.

Glossary of Terms

CoPS	Complex Product Systems “can be defined as high-cost, technology-intensive, and customised capital goods, systems, networks, control units, software packages, constructs and services” (Hobday et al., 2000).
CVM	Customer Value Management is “the setting of organizational strategy in order to maximize the value delivered to target markets, to gain strategic advantage and enhance profitability” (Daniels, 2000).
Ecodesign	Ecodesign “is a process integrated within the design and development that aims to reduce environmental impacts and continually improve the environmental performance of the products, throughout their life cycle from raw material extraction to end of life” (ISO 14006, 2011).
IPSO	Integrated Product Service Offering is “from a life cycle perspective to offer and optimize a solution with a combination of products and services that satisfies and identifies customer need and at the same time increases suppliers’ competitiveness”(Lindahl et al., 2006).
PSS	Product Service System is “a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models” (Goedkoop et al., 1999).
R&D	Research and Development “comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications”(“OECD iLibrary: Statistics / OECD Factbook /Expenditure on R&D”, 2011).

Glossary of Abbreviation

AHP	Analytical Hierarchy Process
B2B	Business-to-Business
CPV	Customer Perceived Value
CRV	Customer Received Value
CoPS	Complex Product Systems
CSM	Customer Satisfaction Management
DRM	Design Research Methodology
KPI	Key Performance Indicator
LCC	Life Cycle Cost
NPS	Net Promoter Score
PDP	Product Development Process
P-I matrix	Performance-Importance matrix
QFD	Quality Function Deployment
QFDE	Quality Function Deployment for Environment
S-CoPS	S-CoPS refers to a specific type of CoPS
S-CoPS provider	S-CoPS provider refers to a specific CoPS provider and its organization
SPIPS	Solution Provider through Integrated Product Service development
TQM	Total Quality Management

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1 Introduction

1.1 Background

The ever-growing population and the demand for improving quality of life in both developing and developed countries puts enormous pressure on the use of natural resources. This is because economic growth is tied to an increase in the volume of products sold by companies, which results in high material consumption. Pollution as a result of high material consumption, together with concern regarding the shortage of natural resources, has resulted in increased attention by scholars and practitioners to find innovative solutions to tackle sustainability of production and consumption problems (Mont, 2002; Tukker and Tischner, 2006a).

Achieving sustainable product development requires a holistic perspective which integrates and balances the different aspects of product development over the product life cycle (e.g. environmental performance, functionality and economy) (ISO 14006, 2011; Luttrupp and Lagerstedt, 2006). Luttrupp and Lagerstedt (2006) present a comprehensive picture of different product requirements including legal issues, safety, documentation, testing, shipping, packaging, maintenance, and disposal that should be considered in the product development process.

From a design perspective, to enhance environmental aspects of products several design strategies known as ecodesign strategies (environmentally conscious design strategies) have been developed, e.g. material substitution (Ljungberg, 2007), life extension (Nes and Cramer, 2006) and design for recyclability (Eilouti, 2009). Ecodesign “is a process integrated within the design and development that aims to reduce environmental impacts and continually improve the environmental performance of the products, throughout their life cycle from raw material extraction to end of life” (ISO 14006, 2011).

Sakao (2009) states that ecodesign is crucial since it has the highest impact on environmental performance over the product life cycle, but it is not sufficient: ecodesign does not address engineering activities and business issues after the design phase. For instance, in the use phase, with the highest environmental impact, engineering activities such as maintenance, upgrade and lifetime extension which could be environmentally beneficial are out of the scope of ecodesign. Mont (2000) also presents evaluation of ecodesign strategies and discusses the ineffectiveness of these strategies to completely address sustainability problems. Ecodesign strategies focus on improving some characteristics of a product or a production system and fail to address the entire process of production and consumption, i.e. economic and environmental issues from a holistic perspective (Mont, 2000; Roy, 2000). For example, when a manufacturer makes a profit through selling a physical product to customer, no matter how eco-friendly one unit of the product may be, the total environmental impact of the products sold by the manufacturer increases over time. This trend increases the use of energy and resource flows, as well as produces more pollution and waste per person (Roy, 2000).

To overcome the limitations of ecodesign mentioned above, several concepts which address both environmental and economic issues have been developed. Among the emerging concepts, the

Product/Service System (PSS) concept (Goedkoop et al., 1999) has been getting increasing attention of industry. Goedkoop et al. (1999) define PSS as “a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models”. The PSS concept could reduce consumption of materials by fulfilling customer value through providing more dematerialized solutions. The integration of service and products in parallel, from a life cycle perspective, has not been clarified in the definition of PSS. The Integrated Product and Service Offering (IPSO) concept extends the definition of PSS by highlighting the importance of integration between product and service over the life cycle. The IPSO can be defined as “from a life cycle perspective to offer and optimize a solution with a combination of products and services that satisfies an identified customer need and at the same time increases the supplier’s competitiveness” (Lindahl et al., 2006). The IPSO not only aims at increasing customer value, but also has the potential to reduce environmental impacts of offerings (Lindahl et al., 2014).

Tukker et al. (2006b) state that the IPSO approach could work for products which have the followings conditions:

1. Products with high cost of operation and/or maintenance
2. Products which require special competences in the design and use phase of the life cycle
3. Products with significant consequences or/cost if not used in a proper way
4. Products with long life

Considering the conditions above, Complex Product Systems (CoPS) (Hobday 1998), an analytical category of products, could be suitable to apply to SPIPS, an IPSO design method. CoPS is defined as “high-cost, technology-intensive and customised capital goods, systems, networks, control units, software packages, constructs and services” (Hobday et al., 2000). The complexity and customization of CoPS requires special competencies, both in the design and use phases. In addition, their life cycle normally lasts for decades (Hobday, 1998). Examples of CoPS include flight simulators, aircraft engines, train engines, systems for electricity grids and offshore oil equipment.

One of the gaps in the current body of knowledge of IPSOs is the lack of empirical data in terms of the contribution of IPSOs in the environmental impact of products (Beuren et al., 2013; Tukker, 2013). Lindahl et al. (2014) are among the few that have, with three industrial cases, quantitatively tried to measure the IPSO’s potential environmental and economic implications. In line with the above, only limited results exist that show how an IPSO design, e.g. the SPIPS method, could improve the environmental impact and customer value of CoPS. Another research gap in the IPSO research arena is the lack of empirical data regarding implementation of the IPSO design method in a real environment (Baines et al., 2009; Tukker, 2013). For instance, there has not been a discussion of the potential influences of SPIPS method implementation in product development processes, Research & Development (R&D) processes, and Customer Value Management (CVM) of an IPSO provider. A case study, showing the contribution of an IPSO design method in environmental performance of CoPS, customer value, business processes and managerial systems of a CoPS provider, would not only be interesting for academia, but would also encourage practitioners to apply an IPSO design method more widely.

1.2 Objective

The overall objective of this thesis is to analyse how Solution Providing through Integrated Product and Service development (SPIPS) (Sakao et al., 2009a), an IPSO design method, can contribute to improving customer value and the environmental performance of CoPS in practice.

SPIPS is chosen as the IPSO design method because it has already been verified for CoPS. In addition, SPIPS has been implemented on a small scale for the case study company and provided satisfactory results. The focus of this research is on the business processes of the CoPS provider, e.g. product and service development processes which are managed directly by the CoPS provider.

SPIPS is a procedure that begins with capturing customer value for each market segment. Then, those customer values which are seen as improvement opportunities (Ulwick, 2002) are deployed to design parameters consisting of product and service by applying a method based on Quality Function Deployment (QFD), which was developed by (Arai and Shimomura, 2005; Shimomura and Sakao, 2007). The method provides designers with the opportunity to focus on the most important design parameters and develop solutions so as to increase customer value. In the last step, the cost of the suggested solutions will be investigated to choose the feasible solutions which not only increase customer value, but also have a feasible cost for the provider.

1.3 Research questions

Improving the physical product has been considered as one of the approaches to decrease the environmental impacts of offerings. For instance, in the case of CoPS the results of some Life Cycle Assessment (LCA) studies (Kannan et al., 2005; Meier and Kulcinski, 2000) show that the environmental impacts of the product could be decreased significantly by improving the applied technology. However, improving the technology of physical products could be limited by major technological barriers. On the other hand, service integration in an offering is seen as a different approach for improving the environmental performance of a product through dematerialization (Beuren et al., 2013; Goedkoop et al., 1999). Beuren et al. (2013) list the ways that PSS could benefit the environment as:

- Consumption reduction via alternative product use.
- Extending the provider responsibility to take-back, recycle, refurbish and reduce waste over the product life cycle.
- Dematerialization of the product via increasing service over the product life cycle.

However, few publications present empirical data (e.g. Lelah et al., (2011) and Lindahl et al., (2014)) to show the economic and environmental benefits of the PSS concept (Tukker, 2013). Thus, extending knowledge and providing more empirical data regarding the contribution of services integration in the environmental performance of CoPS would be interesting, both for academics and practitioners. This calls for the first Research Question (RQ), which aims at describing how the integration of services in CoPS could affect the environmental performance of CoPS.

RQ1. How can an IPSO design method influence the environmental performance of CoPS?

According to Lindahl et al. (2006), an IPSO design method is characterized by having a life cycle perspective with the aim of meeting customer needs and increasing suppliers' competitiveness. In line with the IPSO, customer value management also aims at delivering superior value to customers and increasing the competitiveness of a supplier (Daniels, 2000; Gale, 2009). To manage customer value a provider may use various tools and quality initiatives such as QFD, customer satisfaction management, competitive benchmarking etc. (Gale, 2009). Implementation of a new process, e.g. the SPIPS method, requires considering the context of the organization (Pettigrew, 1987). Yet, little research has been done on IPSO design method implementation for CoPS and its harmonization with existing initiatives for managing customer value. Thus, the second research question aims at dealing with managing customer value for CoPS in the process of an IPSO design method implementation.

RQ2. How can an IPSO design method influence the management of customer values in CoPS?

In today's market, which is characterized by fierce competition and increasing customer demand, particularly for firms in long life cycle industries, R&D is seen as an important strategy to gain superiority and sustain growth (Fortuin and Omta, 2007). However, Fortuin and Omta (2007) discuss how the misalignment between the process of R&D and customer value creates a gap between what customers desire and what the product is designed for.

In order to meet customer needs in a more effective and efficient way some manufacturers are modifying the procedure of their engineering activities prior to product design, e.g. changing the process of their R&D project evaluation to focus on customer value rather than to be "technology push"-oriented (Sakao et al., 2011). In addition, in order to meet customer needs, manufacturers continuously improve the functionality of their products, even in the use phase, due to reasons such as the unfeasibility of designing a perfect product, rapid changes in the customer's needs and the emergence of new technologies (Takata et al., 2004). Thus, it is crucial for a manufacturer to align R&D projects with customer value, not only prior to the design phase but also in the use phase. Furthermore, due to the fact that customer value and provider value are not always the same, a provider requires a balance between its value and those of its customers.

The current literature on R&D project evaluation and selection presents different perspectives on R&D project evaluation (Verbano and Nosella, 2010). A comprehensive literature review on PSS design methodologies shows that 20 dimensions of PSS design methodology and related research areas have been addressed (Vasantha et al., 2012). The contribution of an IPSO design method for R&D project evaluation and the R&D selection process has yet to be addressed, and stipulates that the following questions be addressed.

RQ3. How can an IPSO design method influence the R&D management of CoPS?

1.4 Delimitation

This research is based on a single case study. The IPSO design method SPIPS, which is the focus of this research, is validated with another case in Germany (Sakao et al., 2009a). The generalization of results of this research will be based on these two cases. Compared to the case in Germany, the scope of this research has been expanded through analysing the existing business process of the CoPS provider in order to find the potential improvement opportunities

between SPIPS and other business processes. However, this research is context-dependent, and the results are not necessarily general for other types of CoPS. Thus, the term CoPS in this research is called “S-CoPS”, which refers to the specific product, and the case company is called “S-CoPS provider”, referring to the specific organization and its business processes.

Moreover, dealing with organizational strategy and organizational transformation, which are two main challenges for the servitization of manufacturing firms (Baines et al., 2009), is out of the scope of this research. Furthermore, there are two theoretical approaches toward customer value (Graf, 2007): first, customer value from the provider perspective, and second, customer value from the customer perspective. In this thesis, the focus is on the customer perspective, and the term customer value refers to just that. In addition, social value is not addressed in this thesis.

1.5 Outline

The thesis is divided into to nine chapters. The outline below provides the reader with an overall view of the thesis’ structure, and briefly describes the main content of each chapter.

Chapter 1 discusses the background aim and the research questions of this research. This chapter also includes the motivation behind each research question, as well as the delimitation of the research. Next, **Chapter 2** presents the theoretical framework, which is divided into two sections: ecodesign and PSS design, and customer value.

Chapter 3 then discusses the method used, while **Chapter 4** presents a summary of how each of the appended papers contributed to the thesis. Here the aim, method and contribution of each paper are presented. Following this, **Chapter 5** presents the Product/Service development processes of the Complex Products and Systems provider. The background of the company, as well as its industrial challenges in the marketplace, is described. Furthermore, the organizational structure of the company is presented, along with relevant existing business processes.

Next, **Chapter 6** provides a discussion on the research questions, each of which is presented and answered based on the findings and the literature review. To do so, the content of the appended papers is summarized and elaborated on to provide a brief and concise answer for each research question. **Chapter 7** then presents the conclusions, **Chapter 8** provides some potential future research, and finally, **Chapter 9** presents the references used in the research.

2 Theoretical framework

This section presents the research framework of this study. The section begins with a life cycle perspective for product development, followed by ecodesign and PSS design. Next, SPIPS, the IPSO design methodology employed in this research, is explained. Since QFD is the main method used in SPIPS, the following section presents an overview of QFD. Customer value management from a life cycle perspective and the Analytical Hierarchy Process (AHP) are presented at the end of this section.

2.1 Life cycle perspective for product development

There has been a demand on the manufacturing industry to be responsible for the environmental performance of their products while keeping and improving the functionality of those products (Alting, 1995). This has led manufacturers to extend their design perspective to cover all life cycle stages (Umeda et al., 2012). From the design perspective, the product life cycle includes design, production, use and end-of-life treatment (Cao and Folan, 2012).

The decision making early in the design phase is more important compared to the subsequent phases. As shown in Figure 1, this is because early in the design phase, the freedom of action is high and modification cost is low. In addition, the cost for change increases rapidly over time due to the amount of work needed to be redone. In the design phase, the knowledge regarding the final product is scarce for designers and the information is more qualitative, especially if the product is new. As the product development project progresses knowledge increases, while the scope of freedom of action could decrease if time and cost drive the project. The general design paradox implies that “when design information is needed, it is not accessible and when it is accessible is usually not needed” (Lindahl, 2005). The principal relation between freedom of action, modification cost and product knowledge is depicted in Figure 1.

Figure 1: The relation between “Freedom of action”, “Product knowledge” and “Modification cost” is shown (Lindahl, 2005)

In addition to the design phase, which is the most influential phase, as Fava (1997) states other stages have their economic and environmental impact as well. This calls for a holistic perspective to consider different aspects during the product life cycle to achieve business benefits and improve the environmental performance of products (Fava, 1997).

2.2 Ecodesign

The growing awareness of the design process impacts the environmental performance of product-leading organizations to include environmental performance in the design phase of their products (ISO 14006, 2011). The design process represents a minor part of a product's total life cycle costs and environmental impact. However, decisions made within this process have a huge impact on the product's future life cycle costs and environmental costs (Tischner et al., 2000). Although environmental consideration in the design phase may seem beneficial, an environmentally beneficial change in the design phase may have adverse environmental impacts on the next phases of the product, and lead to increase the total life cycle impact of the product. For instance, reducing toxic material may shorten the lifetime of the product, and thus increase total resource consumption (Roy, 2000).

This limitation calls for a systematic approach to integrate environmental considerations in the design phase and reduce adverse environmental impact over a product's life cycle, which has led to the development of the ecodesign concept. Ecodesign can be defined as “a process integrated within design and development that aims to reduce environmental impacts and continually improve the environmental performance of the products, throughout their life cycle, from raw material extraction to end-of-life” (ISO 14006, 2011).

Ecodesign uses a combination of several strategies to minimize the total environmental impact, which includes: material substitution (e.g. Ljungberg, 2007), life extension (e.g. Nes and Cramer, 2006), design for recyclability (e.g. Eilouti, 2009), and design for reusability (e.g. Yang et al., 2014). The choice of ecodesign tool is very context-dependent. Knight and Jenkins (2009) list several factors (e.g. product requirements, legislation requirements, cost and time required to adopt the tools) that could be considered to select suitable ecodesign techniques. In addition, in the process of ecodesign implementation there are some issues to be considered, namely “use of a common language”, “tailor-made solutions”, and “build-up of a common understanding” (Pascual et al., 2003).

On the other hand, Sakao (2009) shows “ecodesign is obviously crucial, since it is the design activity with the dominant influence”, but it is not sufficient because it excludes control after the design phase. For instance, the business model between the provider and customer which influences the consumption pattern of the product has not been addressed by ecodesign strategies. The traditional business model could increase the total environmental impact of a product sold by a provider. When a provider makes profit through selling more physical product, no matter how environmental friendly one unit of the product may be, the total environmental impact of the products sold by the provider would increase over time (Mont, 2000).

2.3 Product-Service System design

Partly in order to overcome the limitations of ecodesign (mentioned in Section 2.2), the Product-

Service System (PSS) (Mont 2002, Tukker and Tischner, 2006) concept has been developed. The Product-Service System can be defined as “a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and (may) have a lower environmental impact than traditional business models” (Goedkoop et al., 1999).

Concepts similar to PSS are e.g. total care product (Alonso-Rasgado et al., 2004), integrated solution (Windahl and Lakemond, 2006), hybrid offering (Ulaga and Reinartz, 2011), and Integrated Product Service Offering (IPSO) (Lindahl et al., 2009). In general, those concepts are more or less other names for what PSS represents, but there are differences. For instance, an IPSO is the same as a PSS, while emphasizing the integration between product and service. The literature in this arena can be categorized into three main research streams (Sakao et al., 2013):

1. Service and marketing perspective.
2. Sustainability perspective.
3. Engineering perspective.

Figure 2 depicts several processes which are of interest in IPSOs (Sakao et al., 2011).

Figure 2: Processes of interest in IPSOs (Sakao et al., 2011). Note: IPSO = Integrated Product Service Offering; EOL = end of life

From an engineering perspective, the PSS design approach shifts focus from design and sale of a physical product to design and sale of a solution consisting of an integrated product and service to meet specific customer needs (Mont, 2002). The IPSO development process requires dealing with additional dimensions compared with the product development process. Vasantha et al. (2012) present a maturity model for IPSO design with 20 dimensions, of which only three are strongly treated by scholars, i.e. “design process for integrating product and service”, “definition

of new terminologies” and “consideration regarding planning and designing life cycle phases”. An IPSO design process should also define *what* steps should be followed and *how* each step should be performed (Cavalieri and Pezzotta, 2012). The analysis of the most renowned IPSO design methods revealed that a few of them have a life cycle perspective and have contributed in answering the *what* and *how* aspects of design methodologies (Cavalieri and Pezzotta, 2012).

Although research in this area has increased over the last decade, theoretical knowledge is scarce concerning IPSO design (Sakao et al., 2009b), and there is especially a lack of empirical data regarding implementations of IPSO design methods (Baines et al., 2009). The PSS research field can be expanded through addressing the following issues:

- From the design perspective, in the process of developing an IPSO, the need to consider different stakeholders’ value has been emphasized (Bianchi et al., 2009; Mont, 2002). Cavarlie et al. (2013) categorize IPSO stakeholders into three groups: 1. customer/end user, 2. channel, and 3. society and environment. There are a few authors who have addressed both provider value and customer value in the process of PSS design. Geng et al. (2010), for example, propose a method considering customer requirements as well as manufacturing requirements of a provider in the process of PSS design. Their method only considers the engineering characteristic (EC) at a high level of abstraction.
- As discussed in Section 1.3, there is a lack of sufficient empirical data regarding the environmental and economic benefits of implementing an IPSO design method.

2.4 Description of Solution Providers through Integrated Product and Service development methodology

SPIPS (Sakao et al., 2009a) is an IPSO design method which consists of seven steps (from 0 to 6) as shown in Figure 3. The process begins with deriving customer value and cost for each market segment. Market segmentation could be different from case to case. Each company may segment its customers based on product type, geographical areas etc. If information on customer value and cost already exist, Steps 0-2 will be omitted. Step 3 is based on the work by Ulwick (2002), which in turn is based on the developing Performance-Importance (P-I) matrix. The P-I Matrix plots customer value based on its performance and importance scores as shown in Figure 4.

The outcome of this step is a list of customer value/costs which is more important and less satisfactory from the customer’s point of view. The Performance-Importance matrix can be developed through a direct questionnaire as suggested by (Garver, 2003). Step 4, named “translation to design parameter”, is among the core steps. It applies the method developed by (Arai and Shimomura, 2005; Shimomura and Sakao, 2007), which is an extension of the traditional Quality Function Deployment (QFD) (Akao, 1990). In this step, each customer value/cost will be analysed in order to derive important design parameters related to product and service. The design parameters can be gathered through developing matrices similar to those used in QFD. The outcome of Step 4 is design focuses to be used in the next step. Step 5 is brainstorming to find a solution to influence the most important design parameters of product and service to increase customer value/decrease cost for each market segment. Employees of the company with relevant knowledge and responsibility should contribute in this step. Step 6 investigates costs and potential benefits for each option suggested in the previous step. The result

will be the improvement options which increase the customer value/decrease customer cost and have feasible cost for the provider.

Figure 3: The procedure of SPIPS (Sakao et al., 2009a)

High importance	Major weakness	Major strength
	Minor weakness	Minor strength
Low importance		
	Low performance	High performance

Figure 4: Performance-Importance matrix (Ulwick, 2002)

2.5 Quality Function Deployment

Quality Function Deployment (QFD) (Akao, 1990) can be defined as a “set of tools for recording user requirements, engineering characteristics that satisfy these user requirements, and any trade-

offs that might be necessary between the engineering characteristics” (Bouchereau and Rowlands, 2000). A wide range of benefits has been reported as a result of applying QFD including improving reliability, decreasing project change, decreasing time and cost of product development, etc. (Carnevalli and Miguel, 2008). On the other hand, companies which applied QFD have reported some difficulties such as ambiguity in the Voice Of Customer (VOC), poorly defined strength of relationship, too complex and very large tables, too time consuming etc. (Bouchereau and Rowlands, 2000; Carnevalli and Miguel, 2008).

Nevertheless, QFD has been widely applied in different fields such as service development, product development, software development, planning etc. (Carnevalli and Miguel, 2008). Masui et al. (2003) have extended traditional QFD to handle environmental and traditional product quality simultaneously, and developed QFD for Environment (QFDE). QFDE has four phases which provide designers with the opportunity to evaluate design improvement changes on environmental quality requirements. Phases I and II, which are similar to traditional QFD, identify important components which should be in focus during design to address environmental and traditional requirements. After identifying the important design components, through developing Phases III and IV designers are able to evaluate the effect of different design changes in terms of environmental aspects of the product beforehand (Masui et al., 2003).

2.6 Customer Value Management

From a life cycle perspective, customer value can be defined in different “modes”, i.e. “Added Value” in the production phase, “(Customer) Perceived Value” in the purchase phase, and “(Customer) Received Value” in the use phase, see figure 5. Customer satisfaction can also be defined in the use phase as the successor of perceived value and the predecessor of received value (Setijono and Dahlgaard, 2007). Customer perceived value is defined as the value that the customer expects to gain over the product life cycle during the purchasing phase, while the customer received value is the total value that the customer received over the product life cycle after the use phase (Setijono and Dahlgaard, 2007).

Figure 5: Links between added value and received value (Setijono and Dahlgaard, 2007)

According to Garver (2003), practitioners in a B2B context can develop the Performance-Importance matrix through direct questionnaires to capture and evaluate customer value. Setijono et al. (2007) suggest using the P-I matrix to evaluate customer satisfaction by evaluating customer value, which could be used as a tool in Customer Satisfaction Management (CSM) as well. According to the mean-end ladder theory (Gutman, 1982), which implies a network of goals including multiple levels in an organization, CSM can also measure customer satisfaction more accurately by considering the hierarchy of goals in a customer organization. CSM could

measure satisfaction of the strategic value of customers by targeting a higher level of customer organization, and satisfaction of technical requirements by targeting a lower level of customer organization.

In order to capture the strategic value of customers in a B2B context, Crain et al. (2008) suggest a five-step procedure. Ulwick (2002) also suggests a procedure to capture and evaluate customer value consisting of the following five main steps:

1. Plan outcome-based customer interviews
2. Capture the desired outcomes
3. Organize the outcomes
4. Rate the outcomes' importance and satisfaction
5. Use the outcomes to jump-start innovation

The main feature of the proposed procedure is using outcome-based customer interviews to derive customer value, rather than asking the customer direct questions regarding his/her value. The outcome of the proposed procedure is a Performance-Importance Matrix.

2.7 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a decision-making process which “contributes to solving complex problems by structuring the hierarchy of criteria, stakeholders, and outcomes and by eliciting judgment to develop priorities” (Saaty, 2013). Saaty (2013) describes the potential benefits of AHP, including providing an effective structure for group decision making and simplifying decision making of complex issues. AHP has been applied widely in areas such as manufacturing, engineering, education etc. (Vaidya and Kumar, 2006). In the technology management area and R&D project evaluation, there have also been several applications of AHP (Gerdri and Kocaoglu, 2007; Liberatore, 1987; Suh et al., 1994).

AHP, combined with QFD, has also been applied in product design selection (Hsiao, 2002; Kwong and Bai, 2003). QFD provides the importance rating of design attributes, i.e. product and/or service attributes. Design attributes are evaluated based on the importance rating of customer requirements and the correlation between customer requirements and design attributes. As Ho (2008) discusses, in the process of rating customer requirements a certain degree of inconsistency may exist which could have negative influence on the choice of the best product design specification. To overcome this drawback, AHP is a solution to evaluate the importance of customer requirements more consistently.

3 Research Methodology

This section presents the framework and methods used in the thesis. The section begins with a description of the Design Research Methodology (DRM), which is used as the main framework to conduct the research. The section continues with a discussion of the Action Research (AR) methodology, which has been used in combination with DRM to conduct the research process.

3.1 Design Research Methodology

This research adopts the Design Research Methodology (DRM) (Blessing and Chakrabarti, 2010). The DRM consists of four main stages: Research Clarification (RC), Descriptive Study 1 (DS 1), Prescriptive Study (PS), and Descriptive Study 2 (DS 2). Figure 6 shows the links between these stages, the basic means used in each stage, and the main outcomes. The bold arrows illustrate the main process flow, while the light arrows denote the main iterations.

Figure 6: The dotted line depicts stages of the DRM framework followed in this thesis (Blessing and Chakrabarti, 2010)

SPIPS, the IPSO design method applied in this research, has been developed and verified (Sakao et al., 2009a) through the entire procedure shown in Figure 6 with one CoPS provider. This research is mainly a cyclic process between the PS and DS 2 stages, with the aim of evaluating and improving the design method with another CoPS provider. The results from the previous case study (Sakao et al., 2009a) and this research will be synthesized to derive more insight.

3.2 Action Research Methodology

The overall objective of this thesis is to analyse how Solution Providing through Integrated Product and Service development (SPIPS) (Sakao et al., 2009a), an IPSO design method, can contribute in improving the customer value and environmental performance of CoPS in practice. The objective of this thesis contains a “how” question, which is more explanatory and suitable to use in case studies (Yin, 2009). The objective of this research is too broad to be used as a single research question. Thus, more research questions are derived as described in Section 1.3 which

cover different aspects of this thesis. These research questions have one feature in common, namely being “how” questions with the aim of implementing an IPSO design method for CoPS. In addition, as shown in Section 3.1 the RQs are related to a design methodology, i.e. IPSO design with the aim of supporting the existing procedures of manufacturers. Providing answers to the RQs requires implementing an IPSO design method in a real environment for CoPS. This can be done through an action research approach within a case study. Action research is defined as a “kind of collective self-reflective enquiry undertaken by participants in social relationship with one another in order to improve some conditions or situations with which they are involved” (Berg, 2008).

There are two reasons to use action research as a complement to the DRM methodology. As Blessing and Chakrabarti (2010) assert, action research can be used in the DRM as an evaluation approach related to the cyclic process between DS 2 and PS. In addition, action research focuses on drawing conclusions regarding a specific design method in a specific situation, which is in line with the aim of this research, i.e. implementing an IPSO design methodology in a real environment for a specific case. However, one of the difficulties of action research is generalization of the findings. The findings of action research are highly dependent on the context of each research case. In addition, researchers involved in the action research process influence the results. In this research, as described in Section 1.4 the applied IPSO design method is SPIPS, which is utilized for the S-CoPS and in the environment of the S-CoPS provider.

Berg (2008) describes four phases for conducting action research:

1. Identifying the research questions
2. Gathering information to answer the questions
3. Analysing and interpreting the information
4. Sharing the results with participants

The first three phases are performed in this thesis, and the first two phases are further described in Sections 3.2.1 and 3.2.2. The results of the third phase are presented in Section 6.

3.2.1 Identifying the research questions

In the first phase, it is important to define issues important to the participant of the research, and not simply of interest to the researcher. For instance, customer value management and R&D management are considered as two important issues for the S-CoPS provider. The motivation and relation between the RQs are described in Section 1.3.

3.2.2 Gathering information to answer the questions

In the second phase, several methods can be used to gather information, largely depending on the participants’ backgrounds and limitations. There are several methods available to gather data needed for a case study. Yin (2009) lists e.g. the following six sources of gathering information for a case study: documentation, archival records, interviews, direct observation, participant-observation, and physical artefacts. The methods used are presented in Table 1.

Table 1: Data collection methods

	Literature review	Semi-structured interview	Internal document	Workshop
RQ1	X	X	X	
RQ2	X	X	X	X
RQ3	X	X	X	

3.2.2.1 Literature review

In this phase of the action research, for each RQ a literature review was conducted with the aim of providing additional information from similar cases to enrich analysis and broaden the discussion. The literature review included several different kinds of sources such as journal/conference papers and technical reports. For the RQs, relevant key words were selected to narrow down the research findings. The key words included CoPS, investment machine, industrial goods, IPSO, PSS design methodologies, service engineering, R&D management, and R&D project prioritization. Several databases, such as the ISI web of knowledge, were chosen to conduct the literature review. The analysis of the literature was done based on theoretical proposition strategy (Yin, 2009). The theoretical propositions reflected in the RQs shaped both the data collection plan and the analysis of the literature review. The theoretical propositions helped to keep the focus on certain data while ignoring other data.

3.2.2.2 Data collection for Research Question 1

For RQ 1, after conducting a literature review as described above the internal documents regarding existing services and environmental performance of S-CoPS were reviewed. In addition, those managers who were responsible for development of related services were interviewed.

3.2.2.3 Data collection for Research Question 2

For RQ2, customer information from different departments which have direct contact with customers was obtained. In addition, a list of customer expectations from the Customer Satisfaction Management (CSM) system, used in the annual customer satisfaction survey, was collected. Furthermore, in order to develop the value-based QFD different employees from various backgrounds were interviewed in two stages using a semi-structured method. The semi-structured interview uses inquiry with open questions, which allows respondents to share their information and discuss related issues and topics of which the interviewer may not be fully aware.

In the first stage, a list of customer values was derived. Then, using the extended QFD (Arai and Shimomura, 2005; Shimomura and Sakao, 2007), each customer value was deployed into design parameters. Employees from product design, business development, quality, hotline services, online monitoring, maintenance planning, inspection, new unit sales, R&D process, and market support were interviewed to capture their knowledge on the relation between customer values and design parameters.

In the second stage, the four phases of the value-based QFD were implemented through a series of three workshops, with participation of three experts from the company and two researchers as the moderator. The selection of participants in the workshop was based on a recommendation from the head of service R&D. The participants were familiar with the research project and showed interest in sharing their knowledge and experience with the project members. At the beginning of the workshop, the traditional QFD table corresponding to the product module, which had already been developed at the company, was presented to the participants to add service-related customer value in the use phase. In the next steps, the list of service characteristics and service components was suggested to the participants to get feedback. The workshops took about 10 hours in total. After finalizing the four phases of the value-based QFD, a questionnaire was given to the participants to get their feedback regarding effectiveness of the method and potential business processes at the company to apply the method in.

3.2.2.4 Data collection for Research Question 3

Regarding RQ3, the current R&D procedures of the company were analysed through reviewing internal documents and semi-structured interviews with R&D managers. Then, the goal was set in collaboration with R&D managers of the company, followed by a literature review regarding existing methods and procedures for R&D management. The first method, which incorporated a PSS design method, was developed and presented to two managers: a service R&D project portfolio owner and a business development manager.

3.2.2.5 Finding respondents

One of the challenges of this research project was finding the right source of information. Due to the scale of the organization and lack of sufficiently shared documentation, information is spread throughout the organization and kept within individuals. The two techniques, i.e. selection based on personal knowledge (in which an experienced expert of a certain area recommends a respondent) and selection by networks (in which a respondent recommends his or her colleagues who might have more relevant information) (Merriam, 1988) were used in this research. This is because current procedures in the company are not completely documented and information is spread among individuals within the company. Therefore, experts and respondents could help to identify who has the relevant information. The project had a supervisor, a high-level manager who has a general overview of current processes. That person was consulted as one of the main sources for finding the right respondent. In addition, formal documents related to each research question were reviewed. Then, employees who prepared and approved those documents were interviewed as a main source of related information. In addition, the interviewees were asked to describe the current procedures and suggest employees who might have further information.

4 Summary of contributions to the thesis

This section briefly presents the contribution from each appended paper and the corresponding method employed. Table 2 shows the contribution of the papers to each of the research questions.

Table 2: Contribution of appended papers to research questions

	Paper I	Paper II	Paper III
RQ1			
RQ2	X	X	
RQ3			X

Note: X indicates direct contribution of the appended papers to the research questions

Regarding RQ1, the answer is provided in Section 6.

4.1 Paper I: Customer-oriented method to design services: empirical studies with two investment machine manufacturers

The contribution of the author of this thesis from Paper I was implementing, analysing and describing parts of the second CoPS example.

4.1.1 Aim

The aim of this paper is to develop and implement a method to support the service design process in manufacturing industries. The existing methods and tools are reviewed, and the following research questions are selected to be answered. The SPIPS process is proposed as a new method to design new services and improve the product and service development process for CoPS providers.

- Are the methods/tools effective in a case with real industrial scale?
- How efficient are the methods/tools for a real-world problem?
- To which types of industries/offerings are the methods/tools applicable?
- How do the methods/tools fit into the work process a company?

The SPIPS process is proposed as a new method to design new services and improve the product and service development process for CoPS providers.

4.1.2 Method

The SPIPS process is applied for two different CoPS examples, and the empirical results are used as a basis for discussion.

4.1.3 Contribution

The results show that the SPIPS process is an effective and efficient method to design new service to increase customer value for CoPS. The paper describes, in detail, each step of the SPIPS process and shows the corresponding empirical data. Two success factors were identified: the organizational structure of the CoPS provider, which supports cross-functional teams at an early stage for developing new products, and the characteristics of addressed services, i.e. service related to CoPS provided by the manufacturers.

On the other hand, the paper discusses some obstacles and uncertainties in the process of SPIPS implementation. Building up an ontology to be used in service design and knowledge sharing between different divisions is a challenge. In addition, there are three types of uncertainties originating from product, customer and provider which should be overcome in the process of designing a new service.

4.2 Paper II: Integrating PSS design methods with systems for customer value management and customer satisfaction management

The contribution of the author of this thesis from Paper II was implementing the SPIPS method, analysing the existing business concepts at the S-CoPS provider, and writing parts of the results.

4.2.1 Aim

This paper investigates the possibility the SPIPS method's contribution to customer value management and customer satisfaction management at a CoPS provider.

4.2.2 Method

Based on a single case study, the SPIPS process is applied for CoPS and the empirical results are used as a basis for discussion.

4.2.3 Contribution

This paper shows that the IPSO design method could improve the managerial systems and business processes of a CoPS provider. Customer value management and customer satisfaction management are two different managerial systems which could be integrated through applying the IPSO design method. IPSO approach could develop a systematic procedure to analyse the customer dissatisfaction and develop new services/improve corresponding business processes to increase customer satisfaction/customer value.

4.3 Paper III: Incorporation of Product/Service System Concept in R&D for Complex Products and Systems

The contribution of the author of this thesis was developing parts of the proposed process, as well as analysing the R&D processes of the S-CoPS provider and writing parts of the results.

4.3.1 Aim

This paper aims at improving R&D management of CoPS through incorporating the SPIPS method in the R&D project prioritization process.

4.3.2 Method

Based on the DRM methodology described in Section 3.1, a process is developed for and applied at a CoPS provider.

4.3.3 Contribution

The paper presents a process which incorporates the SPIPS method in R&D project prioritization of S-CoPS while considering both provider value and customer value. The process deployed the extended QFD (Arai and Shimomura, 2005; Shimomura and Sakao, 2007) to overcome the difficulty of connecting R&D projects with customer value, which has its roots in the complexity of S-CoPS. In addition, the process considers both provider value and customer value for each market segment to be used as drivers of R&D project management.

5 Product/Service development processes of the Complex Products and Systems provider

5.1 Background of the S-CoPS provider

The company, which operates in the energy sector, has about 3,000 employees in its own organization and is one of the major players in its market. Its products have a long lifetime - up to 25 years - and are sold around the world with a wide range of applications. There are few providers in the market and fierce competition, partially due to the high technological complexity required to produce such products. The market segmentation can be based on the range of output or application of the product, and each market segment may have a different market leader. The company does not have the largest market share, although it benefits from technological superiority in a market niche.

The trend in the market has been shifting from improving technological characteristics of the product, to providing a complete solution for customers to meet a wider range of customer needs. Along with this trend, the company has also shifted its focus from solely improving the technological performance of the product to providing new services and solutions for customers on a wider scale. The mindsets of managers and designers have been changing as well, from being a technology-push company toward being a solution provider. As a result of this change, the share of R&D investment on service has been increasing over the last few years, with the aim of integration between product and service in a systematic manner. However, a big difference exists between the investment on service R&D and R&D for improving technological performance of the product.

5.2 Industrial challenges in the market

The S-CoPS provider faces some challenges in its market. One of the main challenges is the major influence of some customers on the total demand of the market. The requirements of these customers affect the features of new products. In addition, the time and expense of new product development is so substantial that it becomes impossible to develop customized products for each market segment. Thus, the company develops a standard product which has the highest potential profit in all the market segments. Then, the service and maintenance plans are customized for each segment.

Furthermore, the local environmental regulations heavily affect the minimum requirements of customers. The regulations may change in the short term, however, which puts pressure on the product and service development process of the providers. Due to the high complexity of the product and time-consuming development process, it is not possible to quickly respond to the changing customer demands.

5.3 Organizational structure of the S-CoPS provider

The company has three main departments, as follows:

- Service Department
- New Business Unit Department
- Solution Department

All three departments are managed independently and are looking to increase their own profits separately through individual sales departments. However, there are interfaces between all departments in order to share their knowledge and align their strategies. The Service Department and New Business Unit Department both have their own R&D departments. The New Business Unit Department focuses on the design and sales of new products to customers, and analyses the market trends in order to increase opportunity for the company in selling new products to existing or new customers.

The Service Department has direct contact with those customers that have already bought the product. CSM is a management system which is used by the service department to measure customer satisfaction in the use phase. The Service Department aims for the customization of service-product in order to increase customer value for different market segments. There is a close collaboration between the Service Department and the New Business Unit Department to improve the offering. However, the New Business Unit Department first focuses on decreasing cost, aiming at selling more new products, while the Service Department focuses on attempting to decrease the life cycle cost, which may be too difficult due to the design paradox.

The Solution Department has a broader perspective, providing customers with a complete package through turnkey projects including products, services, financial services etc. The solution department buys products and services from the other two departments and operates independently.

5.4 Selection of respondents

As described in Section 3.2.2, the semi-structured interview was one of the methods used for gathering data. The following table shows the positions held by the respondents in this research. Due to confidentiality issues, this table does not include all respondents who were interviewed in the gathering data phase: the respondents who are excluded in Table 3 have a background in business development, quality, hotline services, online monitoring, maintenance planning, inspection, new unit sales, R&D process, and market support.

Table 3: Respondent position

Code	Department	Position	Total time (hour)/Year
R1	Service	Head of Business Development	2h in two sessions/2013
R2	Service	Head of R&D	2h in two sessions/2013
R3	Service	Service R&D Portfolio Manager (1)	2h in two sessions/2013
R4	Service	Service R&D Portfolio Manager (2)	2h in two sessions/2013
R5	Service	Service R&D Engineer (1)	1h in one session/2013
R6	Service	Service R&D Engineer (2)	1h in one session/2013
R7	Service	Business Development Manager (1)	2h in two sessions/2013
R8	Service	Business Development Manager (2)	2h in two sessions/2013
R9	Service	Business Development Manager (3)	2h in two sessions/2013

5.5 New product development and new service-product development process

The product and service development process at the company consists of two processes called Strategic Product Planning (SPP) and Product Development Process (PDP). SPP includes two processes:

- R&D portfolio planning
- Product and innovation strategy process

Both the Service Department and the New Business Unit Department follow the same procedure for the new product or new service-product development process. In addition, there is an integration process to share knowledge between the two departments. For instance, the Service Department analyses and reflects on technical maintenance requirements of a certain level of availability in the design phase of the product.

5.6 Strategic Product Planning

Strategic Product Planning (SPP) is a process to evaluate the market trends and customer needs as well as a competitor's offerings compared to the company's offerings, and which prioritizes R&D projects. The outcomes of SPP are a Product Requirement Specification for new product development or improvement of existing products. The Service Department and the New Business Unit Department are responsible for performing the SPP process separately, while sharing information in order to improve the competitive position of the company and to meet customer requirements. The outcome of SPP for the Service Department is a list of projects which will be taken during the next fiscal year by the R&D department. The results of interviews with R&D management at the S-CoPS provider are presented in Table 4.

Table 4: Results of interviews on R&D management

Comment	Respondent								
	R1	R2	R3	R4	R5	R6	R7	R8	R9
There is a need for a more systematic process for R&D project evaluation.	*	*	*	*	*	*	*	*	*
CSM and R&D management should be connected more systematically.	*	*							
There is an improvement opportunity in cost reduction of R&D projects through synergies between R&D projects.		*	*						
The process of R&D project prioritization could be improved through close collaboration with the Engineering Department.		*	*	*					

5.7 Product Development Process

The Product Development Process (PDP) is a project management model for product development. The PDP could be applied to new product development or a service-product such as modification and upgrade. The PDP is also one of the managerial means for process improvement, along with the Six Sigma team.

The PDP has five major steps: project initiation, design, sales preparation, design implementation, and validation. The PDP process is based on the academic PDP model (Stage-Gate-Model) (Cooper, 1990), and is called a “waterfall” process (Erdogmus and Williams, 2003) because of its one-way nature. The product specifications are frozen at the beginning of the product development process, in design, and it is too costly to go back and change them. There are 10 gates and reviews for the major PDP. Before a gate meeting has taken place, a review meeting is held to determine whether the requirements to hold the next gate meeting are fulfilled. Depending on each project requirement, different people from the three main departments will participate at these meetings.

5.8 Customer Satisfaction Management

Customer Satisfaction Management (CSM) consists of three main processes, namely: customer satisfaction survey, user group/customer meeting, and customer complaint management operation. The three processes aim at measuring and improving the level of customer satisfaction.

- The customer satisfaction survey is an annual survey which is run by the Service Department. The result of this survey is the Net Promoter Score (NPS), which shows the percentage of “promoter customers” minus “dissatisfied customers”.
- The user conference meeting is a regular conference between customers with the same product and the company to discuss the customers’ concerns and administer customer surveys.

- The customer complaint management operation targets unsatisfied customers to provide them with quick solutions for their problems.

The results of interviews with CMS at the S-CoPS provider are presented in Table 5.

Table 5: Results of interviews on customer satisfaction management

Comment	Respondent						
	R1	R2	R3	R4	R7	R8	R9
The interface between different initiatives should be improved to increase customer satisfaction.	*	*			*	*	*
The New Business Unit Department just focuses on decreasing the purchasing cost of the product.	*	*			*	*	*
The Service Department focuses on decreasing the LCC of the product.	*	*	*	*	*	*	*
CSM synthesizes customer information from different market segments.					*		

5.9 Service and environmental performance of the S-CoPS

In general, after the design phase, upgrading efficiency and/or output of S-CoPS is too difficult according to the design paradox (Lindahl, 2005). This assertion is reinforced in this S-CoPS by the fact that the technology chosen is highly influential on the environmental performance, and a high degree of interconnectivity among the product's modules make improvement (Table 6) on the environmental performance of the S-CoPS difficult by a service in the use phase.

Table 6: Results of interviews on service contribution in environmental performance of the product

Comments	Respondent	
	R5	R6
Not having information about the profit model of customers is a main barrier to commercializing the service for improving efficiency and output of the product.		*
Lack of information about the operational profile of the product is the main difficulty in offering lifetime extension service.	*	*
The designers of the product may leave the company or the design team after the release of the product to the market.	*	
There are major technological barriers in improving efficiency of the product in the use phase.	*	
The newly developed product requires several years of testing for a limited number of customers before large scale commercialization.	*	

Nevertheless, the company offers some services in the use phase in order to improve efficiency and the output of the product. From a single experiment with one of the services, before

performing it, the output of the product decreased by 12% over three weeks. The efficiency also decreased by 2.5% over the same period. According to the data from the experiment, just after performing this service, the output of the product increased by 8% and efficiency increased by 2.5%. This data shows this service's potential for improvement in general. In addition, the information regarding the negative environmental impacts that resulted from performing this service (such as pollution from transportation and from consumables to perform the service with) are essential to be considered in order to have a more accurate evaluation. Yet, there are some barriers that should be overcome in order to offer this service, as explained in the next paragraph.

This service could be performed periodically over time to improve efficiency and output. However, performing this service requires stoppage of the customer's production line. Therefore, in addition to the cost of performing this service, there is profit lost for the customer due to stoppage in production. Defining an optimum frequency for performing the service is a critical task when offering this service. Provided they had access to the customer business model, the provider could define the optimum frequency for performing the service; otherwise, the customer can define the optimum time interval for performing the service. One barrier to offering this service is the technological maturity of the product. When a product is new on the market and the CoPS provider does not have enough experience and knowledge regarding performance of the product both environmentally and economically, the provider prefers to focus on improving the functionality of the product and to correct unexpected faults rather than offering new services to customers. After reaching a certain level of product technological maturity, the provider could offer this service to add more value to customers.

The company also offers another service called "lifetime extension", aimed at extending the lifetime of a product after its nominal lifetime, which optimizes resource consumption. In this service, the remaining lifetime of the main components will be estimated, and some components may be replaced with new ones based on a new maintenance plan for the remaining life cycle. From a practical perspective, one prerequisite to extend the lifetime of a product is having precise information on the operational profile of the product over the life cycle. There are some barriers in collecting this information. First, the operational profile of the product could reveal sensitive financial data about a customer. Second, third parties may perform maintenance on the product and keep detailed information. Third, the cost of the remaining lifetime estimation depends on the knowledge of the product's designers. The designers involved in the product development process may leave the company or have another position. This kind of knowledge could be gathered early in design phase.

6 Discussion

As the third step of the action research procedure (described in Section 3.2), this section presents a discussion of each research question using the results of the case study and literature review. In addition, at the end of the section the insights gained from the results of the two case studies are discussed.

6.1 SPIPS contribution in environmental performance of CoPS

The literature review of the PSS research field shows that there has been qualitative discussion supporting potential environmental benefits of PSS offerings compared to traditional sales (Beuren et al., 2013; Tukker, 2013). Tukker (2004) shows semi-quantitatively that different types of PSS offerings can contribute to the environmental performance of products, but the extent of the contributions varies. Product-oriented PSS does not provide a radical improvement in terms of resource efficiency, while use-oriented and result-oriented PSS have a higher potential for improvement (Tukker, 2013). However, there is a lack of sufficient empirical data to show whether PSS can result in environmental and economic benefits.

One of the few empirical results showing the environmental and economic contribution of the IPSO is presented by Lindahl et al. (2014). The IPSO can bring environmental and economic benefits compared with traditional sales through performing engineering activities over the product life cycle phases of e.g. design, recycling, reuse and maintenance (Lindahl et al., 2014).

The empirical results of this research show that SPIPS can contribute to the environmental performance of S-CoPS in the use phase. The main environmental impacts of S-CoPS are often from the use phase, and depend largely on the performance of the applied technology. According to results from LCA studies of similar products (Kannan et al., 2005; Meier and Kulcinski, 2000), energy consumption during operation is the largest contributor to greenhouse gas emissions. Meier et al. (2000) show that energy consumption accounts for 82% of the total greenhouse gas emissions over the product life cycle. Construction, operation and maintenance, decommissioning, and land reclamation comprise about 1% of the life cycle emissions (5 tonnes CO₂ equivalent emitted per gigawatt-hour electricity produced (tonnes/GWeh) of 382 tonnes/GWeh). This means that an improvement of applied technology could have a major contribution in emissions reduction over the life cycle. However, according to the results of this research (Table 6), there are major technological barriers in improving efficiency of the physical product in the use phase. In addition, the results of this case study show that there is a certain service (described in Section 5.9) which outperforms existing technological solutions for changing the physical product in terms of increasing efficiency and power output of the product in the use phase. The SPIPS process could contribute to facilitate the integration of service in the IPSO design process with a holistic perspective.

As shown above, it seems that SPIPS can contribute to environmental performance of energy and material consumption in CoPS during the use phase through integrating environmentally beneficial service. In the design phase, as the most influential phase, through developing the value-based QFD, SPIPS could help designers to evaluate and compare the effect of different options on customer value including the environmental performance of S-CoPS.

6.2 SPIPS contribution in customer value management of the S-CoPS provider

Customer value can be defined in different “modes” over the product life cycle (Setijono and Dahlgaard, 2007). According to the results of the case study, the S-CoPS provider uses different initiatives to manage customer value, which can be categorized into two main groups:

- Initiatives aiming at selling more new products; and
- Initiatives aiming at improving the satisfaction of customers who already bought a product.

However, these two types of initiatives are related as described in Paper II. SPIPS implementation could support both types through providing a basis to improve the whole system more systematically.

6.2.1 Systematic improvement of customer value management

The S-CoPS provider defines a list of strategic and operational customer values and uses technical and organizational Key Performance Indicators (KPIs) related to each customer value. The KPIs aim to measure performance of different business processes supporting each customer value. SPIPS improves management of KPIs and their corresponding processes, as described in Paper II. To do so, SPIPS generates a list of product and service design parameters (Arai and Shimomura, 2005; Shimomura and Sakao, 2007) related to different customer values, some with strategic importance and others with tactical. Those parameters which have strategic importance affect the customer's business on a long-term perspective, while others have tactical importance affecting a lower level of the customer's organization. These parameters can be used to improve the whole system in both the short-term and long-term. For instance, the factors affecting certain customer values, e.g. product availability and reliability, are defined while indicating the role of service and product in both the short-term and long-term to increase each customer value. In the process of defining these factors the role of the provider, supplier and third parties are considered. These factors not only cover technological improvement of a product, but also consider the role of service, in terms of a preventive and proactive maintenance approach and corresponding managerial issues. Thus, these design parameters provide a basis to improve the whole system more systematically. As a result, the company can increase its competitiveness through managing the product/service at a strategic level and increase customer satisfaction by providing customized offerings for each segment.

6.2.2 Improving new service design process

As an outcome of SPIPS implementation, a list of design parameters (Arai and Shimomura, 2005; Shimomura and Sakao, 2007) is generated which relate to different customer values. SPIPS identifies the most important design parameters affecting each customer value, which in turn provides a basis to generate new ideas so as to increase customer value. In addition, the design parameters can be used to examine the effectiveness of new ideas regarding added value for the customer. For instance, as described in Paper II two design parameters, “time between analysis of component/function history” and “quality of information about component/function

history”, were found to have a strong impact on “available operation time of machine”, one of the important customer values. An early warning system was the new service idea created to improve “available operation time of machine” based on the strategy of increasing customer value with focus on the two design parameters.

6.2.3 Knowledge integration in process of product and service development

Over time, knowledge of the S-CoPS provider and its customer increases regarding the maintenance and operation of a product. Due to characteristics of the S-CoPS, such as complexity and intensive engineering as well as having long life, a wide range of specialists from different disciplines are involved in the operation, maintenance and improvement of S-CoPS. Thus, different kinds of experiences, both in customer and provider organizations, will be accumulated over time. One challenge is how to integrate this spread knowledge and systematically use it in the process of product /service design.

The results of this case study imply that value-based QFD is potentially an effective tool to integrate service-related knowledge in the design phase of product development. The value-based QFD addresses components of product and service in the same manner. In Phase I and Phase II of the value-based QFD, a wide range of employees with different backgrounds and experience were interviewed to capture service characteristics and service components of S-CoPS. In addition, in Phase III and Phase IV of the value-based QFD, different specialists could benefit from the opportunity of systematic knowledge sharing.

6.2.4 Improving the interfaces between different management systems

The S-CoPS provider uses different management systems such as CVM, CSM, and R&D management. These systems have interfaces with each other and use different KPIs to evaluate the performance of business processes. The results show that SPIPS has the potential to integrate different managerial systems as described in Papers II and III. For instance, customer value and customer satisfaction are managed through different procedures. The SPIPS has the potential (as described in Paper II) to improve customer satisfaction management through analysing each customer value behind customer dissatisfaction, and identifying the most important factors that cause dissatisfaction. In addition, each company has its own strategic value regarding its competitive position, future growth etc. By extending the SPIPS (as described in Paper III) a procedure is developed which not only relates R&D projects to customer value and consequently customer satisfaction, but also considers internal strategic value of the S-CoPS provider as drivers of R&D management. Thus, the result of the procedure has the potential to unify the three systems, i.e. CSM, CVM and R&D management, more systematically.

6.3 SPIPS contribute in R&D management of S-CoPS provider

In today’s market, which is characterized by fierce competition and increasing customer demand, particularly for large firms in long life cycle industries, R&D is seen as an important strategy to gain superiority and sustain growth (Fortuin and Omta, 2007). Lin et al. (2002), based on some

empirical data (Klepper, 1996; Utterback and Abernathy, 1983), consider R&D in a sequential pattern over the product life cycle, e.g. product R&D with focus on product differentiation followed by process R&D with focus on manufacturing cost reduction. This categorization of R&D focuses on selling more new products to customers, and does not deal with the product in the use phase. However, customer demand may change even in the use phase in terms of improving the features of product or service. In addition, new technologies may emerge which create new opportunity for customers and providers to take advantage of (Takata et al., 2004). Thus, R&D could continue to add value to customers who already bought the product so as to increase Customer Received Value (CRV), see figure 7.

Figure 7: Different “modes” of customer value and R&D activities over the product life cycle of a S-CoPS provider

R&D in the use phase of the S-CoPS, i.e. service R&D, requires dealing with some challenges including handling the complexity of decision making and considering the heterogeneity of the stakeholders' perspectives. In addition, there is a need to balance between provider and customer value while prioritizing R&D projects. Provider value and customer value are not always the same. In some cases, a provider may have to offer new services just to keep its competitiveness with competitors, while these services do not generate enough profit for the provider.

To handle these issues, after conducting a literature review, the process presented in Paper III is developed and presented to the S-CoPS provider, and which got positive feedback. The proposed process is designed to meet requirements of the S-CoPS provider with the aim to close the gap which often exists between R&D process and customer value (Fortuin and Omta, 2007).

The proposed process could be improved by considering more issues in the R&D project evaluation. For instance, provider value could highlight issues such as strategic value, economy, cost, technological factors etc. (Verbano and Nosella, 2010). In addition, there are different perspectives on R&D project evaluation between the Service Department and the New Business Unit Department which could be addressed in the proposed process. The Service Department focuses e.g. on LCC, while the New Business Development Department tends decrease the purchasing cost to increase sales of new units of S-CoPS (Table 5). The trade-off between these two perspectives could be addressed in the process of R&D project evaluation.

6.4 Value-based QFD

Value-based QFD is a combination of the extended QFD by Arai and Shimomura (2005) and Phases III and IV in QFDE (Masui et al., 2003). It has been applied for a module of S-CoPS. Through Phases I and II, the designers can identify which quality characteristics (consisting of product and service) and components should be in focus in order to satisfy customer value in an efficient manner. Phases III and IV of value-based QFD are the same as those in the QFDE method (Masui et al., 2003).

Value-based QFD is deemed as a useful method to integrate service knowledge in the product design phase. However, there are some difficulties in applying the method. Similar to traditional QFD, value-based QFD is a time-consuming tool and there is ambiguity in defining the correlational strength (Bouchereau and Rowlands, 2000; Carnevalli and Miguel, 2008). In addition, it was perceived that the ontology is an important issue when defining service characteristics (Sakao et al., 2009a). Due to the intangible nature of service, designers may have different understanding of terms used in value-based QFD; thus, developing a service ontology is essential to effectively applying value-based QFD.

6.5 Insights gained from the two cases

The results of the German case study (Sakao et al., 2009a) and this research show that SPIPS has the potential to be applied to at least the two different types of CoPS. The product in the German case is an investment machine with a long life cycle. During the use phase, the operation and maintenance of the German case product requires special competency, and the cost of misoperation is high. The characteristics of S-CoPS in this case study cover all features of the product mentioned in the German case. The empirical findings of this research, together with the findings of the German case study (Sakao et al., 2009a), support the argument by Tukker et al. (2006b) indicating that the IPSO approach could work for a product with similar characteristics to those mentioned above.

In addition, the results revealed that there are some difficulties in the process of SPIPS method implementation similar to the ones mentioned by (Pascual et al., 2003), namely “build up a common understanding” and “use a common language”. Due to the interdisciplinary nature of the IPSO design method, there is a requirement to extract knowledge from different employees with various backgrounds and change existing routines.

Related to the above, employees may show resistance against changing their routines. Thus, a common understanding regarding the importance of information sharing between different employees, and the willingness to change existing processes in favour of an IPSO design method, are essential. One way to build up this common understanding is to clarify the potential benefits of applying SPIPS.

Furthermore, as Pascual et al. (2003) mention, building up a common ontology among different departments is another difficulty in the process of a new design method implementation. In the case of SPIPS implementation, a common ontology is more essential due to the fact that service is intangible, and experts from different backgrounds may not have the same understanding of terms when sharing their information and evaluating design parameters. This issue becomes even

more critical for S-CoPS, due to the cooperation of a wide range of experts who work with each other throughout the product life cycle. Thus, developing an ontology of service and product design parameters during SPIPS implementation is a crucial task to increase the efficiency and effectiveness of process implementation.

7 Conclusion

This research presented the findings of the SPIPS method for an S-CoPS provider. The results showed that there are several potential improvement areas for the S-CoPS provider in applying SPIPS.

7.1 How an IPSO design method can influence CoPS environmental performance

The results of this case study show that the SPIPS method can contribute to the environmental performance of S-CoPS. In the design phase, as the most influential phase, the SPIPS method can provide different options to address the environmental performance of S-CoPS. In the use phase of CoPS, often with the highest environmental impact, the SPIPS process could contribute to facilitate the integration of service in the IPSO design process with a holistic perspective.

7.2 How an IPSO design method can influence the management of customer value of CoPS

SPIPS provides a basis to systematically improve customer value management. Discovering the correlation between different design parameters and customer value provides a basis for managers to focus on the most important elements influencing customer value. In addition, the fact that customer satisfaction and customer value are related to the design parameters could also be used for improving customer satisfaction management.

The results also implied that the SPIPS method can help the S-CoPS provider to systematically take advantage of knowledge integration among different departments. Implementing value-based QFD, different expertise in product design, service design, marketing, service support etc. could help share their knowledge. This could help to improve the information flows in the S-CoPS provider organization.

7.3 How an IPSO design method can influence the R&D management of CoPS

The SPIPS method could contribute in R&D management of CoPS through defining characteristics and components that can be used in R&D project prioritization. The analysis of the results of the German case study and this research show that SPIPS is an effective method for S-CoPS. However, there are some challenges to consider in order to ensure implementation of the method. These challenges can be summarized as facilitating the change process for implementation of the SPIPS method, and building up a unified ontology for different departments of an organization.

8 Future research

The following presents some potential research topics to be pursued as the next steps of this research.

The value-based QFD, described in Section 6.4, is applied for one module of S-CoPS, and most of the data about that application is classified. Both from a practical and a theoretical perspective, one interesting research topic would be to conduct additional studies in order to further evaluate and increase the applicability of the value-based QFD for CoPS.

A second is to investigate change management aspects required to implement the IPSO approach. There is little empirical data discussing the challenges of PSS concept implementation in a real context. The PSS concept could be realized through an organizational transformation (Baines et al., 2009). Organizational transformation influences organizational mission and strategy (Burke and Litwin, 1992) as well as culture, structure, power distribution and the control and creativity pattern of an organization (Maes and Van Hootegeem, 2011). Proper managerial approaches to handle challenges of changing culture, structure, power distribution and control of an organization originating from PSS concept implementation have not been sufficiently elaborated.

A third potential research area is investigating the possibility for an IPSO design method to be implemented with other methods such as Six Sigma, TQM, etc. Those methods are widespread in industry, and a provider may benefit from implementing an IPSO design method to get synergetic effects with these methods.

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