A framework for conceptualisation of PSS solutions: On network-based development models

PhD Thesis

Krestine Mougaard
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Abstract

Manufacturing companies are changing. More and more companies are taking greater responsibility for their products, expanding their customer relationships and providing new sets of service offerings. Increasing amounts of manufacturing companies are even switching from offering products (e.g. trucks) to offering performance (e.g. transport solutions). This transition is challenging, as it puts great demands on the company's capabilities, both within the company and externally, in the company's inter-organisational relationships. Taking greater responsibility of the product performance includes greater risk for the manufacturer, for which reason network capabilities become vital. Relationships to suppliers – and to suppliers´ suppliers – become essential factors in securing high-quality products, availability assurance, and suitable cost. Likewise, the customer relationship changes from a transactional to a relational interaction, in order to proactively meet the customer's changing needs and establish to a continuous information flow, allowing preventive maintenance. Dissolving the sequential value chain into a collaborative ecosystem of stakeholders is a necessity, when offering Product/Service-System (PSS) solutions. Altered relationships and roles embracing the success of all involved stakeholders is one way (arguably, the only way) to a successful PSS.

Danish maritime suppliers are involuntarily facing this challenge; a lifeline of large order books from the Danish OSS shipyard at Lindø, near Odense, was cut with its closure in the early part of the second decade of the 2000's. This forced suppliers to switch their focus from the shipyard to the shipowner. Thus, in one year the business changed from a product focus to an after-sales focus. This research project, which has been part of the Danish Innovation Consortium PROTEUS (PRoduct-service/system-Tools to Ensure User centred Services), was carried out at the Technical University of Denmark at the Section of Engineering Design and Product Development. The project's aim was to investigate how to support the Danish maritime industry in this upheaval and change towards a new mode of business- and product development.

The research presented in this thesis is based on action-research, involving all ten companies participating in the PROTEUS consortium, plus a comparative case study of MAN PrimeServ Frederikshavn and Alfa Laval Aalborg.

The main contributions of the thesis are the following:

- A comprehensive longitudinal empirical study across a whole industry sector, which was in transition from product- to product/service-system oriented business.
- A theoretical foundation for PSS development, with a particular focus on network collaboration. In addition, a contribution to the theoretical knowledge about how the network paradigm "network oriented product development" and PSS theory can be assessed and developed.
- An objectively derived normative framework of combined network-oriented PSS development, based on theoretical and empirical findings and verified in case companies.
- Three new PSS tools to support PSS conceptualisation.
- Contributions to the PROTEUS Workbook series – communicating the results of the PROTEUS research consortium to both academics and industry practitioners.

In loving memory of my Dad…

Preface and acknowledgement

As a student at DTU following the programme entitled Design & Innovation, an integrated part of my education has been within Product/Service-Systems (PSS) and the Socio-technical aspects of the engineering practice. I finalised my bachelor's degree through a bachelors project (polyteknisk midtvejsprojekt) which I carried out together with three other classmates (Marie Brøndum Bay, Line Neugebauer and Camilla Fisker). The aim of the project was to support the maritime industry with normative tools to conceptualise PSS solutions. During this time my enthusiasm for PSS grew and deeply spurred my interest for the field. My supervisor Tim McAloone and at the time my bachelor project co-supervisor and co-teachers Adrian Tan and Detlef Matzen put much effort into applying for an innovation consortium to continue the research within PSS with focus on the maritime industry. Three attempts later the PROTEUS consortium was born in 2010. During this period I had: enjoyed life as a hard-working student; been abroad eight months for an internship within the WorkSpaceFutures department of Steelcase; finalised my studies as M.Sc.; trialled the university work life through a one year research assistant position; and was ready and lucky to get the opportunity to become a researcher within the PROTEUS consortium, as a PhD student.

The process of finalising the PhD studies has brought me large professional and personal development. And in this process I have met and worked with a number of people whom I would like to thank:

Firstly I am deeply grateful to my supervisor Tim McAloone, who gave me the opportunity to take part in this adventurous journey of the PROTEUS consortium. Thank you for all the vast amount of support and encouragement during my studies, which I could not have been without. Many thanks to my co-supervisor Tom Howard from whom I have received endless amounts of inspiration and invaluable supervision. Thank you both for not giving up on me during the hard times.

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To the PROTEUS Research Team: Niki Bey for all the enthusiasm and good advice. To Adrià Garcia i Mateu, particularly with the dissemination of our results to industry through our Workbook series. Also thank you to Juliana Hsuan for sparring, encouragement and big smiles. Also thank you Birna Månsson, you were greatly missed when you moved to Novo Nordisk. Lastly also a big thank you to all the students that have been collaborating with us, either during your bachelors or masters projects. A particular thank to Poul Javier supporting my research activities at the PrimeServ Case study.

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To all of you I met during my research stay in the US at Stanford, thanks for making my visit a trip of a lifetime. To my fellow researchers at the H-Star Institute and CDR, thank you for making it possible for me to go on exchange. Particularly a big thank you to Larry Leifer, Martin Steinert, Adam Sheppard and Gabriel Aldaz – thank you for inviting me into your CDR group and for all the great times we had. To my two roommates Lauraire Jérémy and Gabriela Calderon – thank you for moral support and many extremely fun moments in California.

To the Danish Agency for Science, Technology, and Innovation (DASTI), the Danish Maritime Foundation (DDMF) and The Technical University of Denmark (DTU), which were the funding partners. To all the consortia industry partners: MAN PrimeServ Frederikshavn (Tom Samson and Rikke B. Knutzen); Alfa Laval Aalborg (Hans-Henrik Jensen, Hans Henrik Jensen, Ejnar Siig Christensen and Søren P. Mortensen); Emerson (Jens-Peter Thomsen); YIT (Jan Møller Hansen) Novenco Fire Fighting, Hempel; PresVac; NorecActa; Klinger; Lloyds ODS, and The Danish Maritime Branch Organisation (Jenny Braat). To our technical service partner IPU Product Development. To the company Rassvet for building the back-office and interface of the PSS Configurator.

To my new colleagues at DTU Skylab, thank you for being great, what a wonderful team we have. I feel lucky.

To my friends, I miss you greatly – there is not a single friend of mine that I have not missed daring life celebrations, struggles, or just everyday moments with, during the long process of finalising the thesis.

To my family, thank you all for being a big part of my life. To Jens, Anne and little Carl thank you for all your kindness and understanding. To my mom, whom I respect and love, you will always be a big inspiration in my life.

Most importantly to Ali my love, I can't wait for our future adventures. Thank you for your patience, gentleness and never ending encouragement.

Copenhagen, December 2015

Krestine Mougaard

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1.

Introduction

1. Introduction

This chapter presents the overall research object and the focus for this particular project, by presenting both the research field and the industrial research foundation and by stating the knowledge gaps and challenges in these. The Innovation consortium PROTEUS, which this research project has been part of, is introduced and its position herein elaborated. Furthermore, a brief overview of problem statement, delimitation, and research questions are given. The chapter finalises by presenting the outline of the thesis, which can act as a reading guide to the work presented, together with a scope of the intended audience for the thesis.

The ever increasing speed of technology development; continuous advancement in communication patterns, channels, and communities; adaptation of new ways of collaboratively organising business; industrial overconsumption; and scarce natural resources—all contribute to a global economy, where challenges and new opportunities emerge with constantly growing velocities.

Today manufacturing companies experience a change in value creation—a shift in thinking—where value based on ownership of goods changes to value based on use, performance, or experience. In this context, manufacturing companies' responsibilities are seen to extend to cover the full product life cycle, where producers/providers move towards ensuring quantified availability and function delivered over time, with a focus on value-in-use, through collaborative relationships. Instead of selling a physical product according to traditional virtues, such as product cost, timely delivery and technical quality, companies increasingly offer advanced integrated product/service packages, within which a myriad of through-life services and maintenance activities are offered—all of which are aimed at the technical system, the user, or the operator of these. In such a new environment, improving customers' business becomes a key focus, as manufacturing companies become more dependent on the operational success, in the same tempo as risk and cost become increasingly interdependent. Success and competitive edge become the collaborative achievements between customer and provider.

The transition towards the development and operation of integrated product/service solutions and the creation of new collaborative intra- and inter-organisational structures to achieve this is the main theme of this thesis.

1.1 Ecosystem perspectives on the rise in PSS

In literature a consolidation towards a multiple stakeholder approach within the PSS research field has taken place. Almost all PSS frameworks have so-called 'ecosystem' perspectives inherent but though integrated and represented in different ways. An ecosystem is comprised of multiple stakeholders, which in combinations and through interactions constitute the surroundings of the PSS, it is in the ecosystem the PSS occurs, perform, and through which it will be developed, sustained, and evaluated. Ecosystem is also referred to as actor network and stakeholder network.

Some PSS frameworks include ecosystems explicitly in the PSS dimensions, e.g. (Mont 2002; Tan 2010; Matzen 2009), within which the ecosystem, is represented as network and infrastructure, and positioned as a vital element to include in the analysis, evaluation and development of a PSS. The many PSS transitioning frameworks also stress the importance of an organisational change, when shifting business strategy towards a more service-oriented business (Martinez et al. 2011a; Davies et al. 2006). The organisational change includes intra- and inter-organisational change, shifting the view on value-creation from a sequential value chain towards a so-called 'value system', where value creation crosses time and place – and appears in new stakeholder constellations (Normann 2001). In some interpretations, a whole new ecosystem mind-set is suggested, for example when viewing '*companies as flexible networks*' (Manzini 1999).

The explicit view on the ecosystem within the PSS research field, has thus far not brought a convergence in the terminology (Tan et al. 2010; Matzen 2009), nor any unified methods to integrate ecosystem perspectives into the different phases of the PSS development process. Baines et al. (2005) describe a decision process for strategic positioning in the value chain, using vertical and horizontal integration, and Wise and Baumgartner (1999) present the notion of moving downstream by introducing a set of parameters to assess the attractiveness of a move within the value chain, closer to the customer. Windahl and Lakemond (2006) identify a set of six factors important to PSS development, from which *strength* of relations and *position* in the network are mentioned. Tan (2010) uses a stakeholder network analysis when describing the change in a PSS, and presents a framework for PSS strategy development, where both intra- and inter-organisational relations are integrated. Manzini et al. (2004) present a framework for Solution-Oriented Partnerships, where the relationships within the ecosystem should be taken into account and integrated in new PSS methods.

In general, emphasis is put on the ecosystem perspectives of a PSS, and multiple scholars call for more research within this area of the PSS research field, such as; (Lockett et al. 2011; Windahl 2007a; Mont 2004; Tan 2010; Matzen 2009; Ulaga and Eggert 2006).

Besides the need to focus on the ecosystem perspectives within the PSS research field, there is a need to increase focus on the capital goods sector and its complexities (Ravald and Grönroos 1996; Windahl 2007a), with a focus on business to business relations (Baines et al. 2011; Davies et al. 2006; Oliva and Kallenberg 2003). In general the research field needs to move away from conceptual studies, towards real-life cases (Windahl 2007a). Normative methods and processes of how companies can move towards an integrated product/service-oriented business are needed (Tan 2010; Manzini et al. 2004; Mont 2004; Lockett et al. 2011; Matzen and McAloone 2006). Research presenting case studies with the observation of actual PSS conceptualisation and development within organisations is scarce (Windahl 2007a).

In parallel to the PSS research field, business innovation and management scholars have increased their focus on the importance of the ecosystem perspectives; but also here the terminology has not yet stabilised. The notions of *network capability* (Ring and Van de Ven 1994), *process innovation* (Tidd et al. 1997), and *network management* (Möller and Halinen 1999) – to mention but a few examples – bring valuable concepts rich on details, that to some extent are similar but not yet thoroughly investigated for their implementability to the PSS research field. Furthermore, using these as points-of-departure for the systematic development of new methods and tools to use in PSS development and conceptualisation has not been seen.

The research gap identified for this PhD project is as follows: Within PSS research, ecosystem perspectives are vital. They are complex and difficult to approach, yet no convergence in terminology exists to describe these. Multiple scholars argue that the PSS should be seen as a network of stakeholders, where the competitive edge is a collaborative achievement, though methods and development processes are limited to guide the industrial practitioner towards this. Observation of real-life cases with actual development and conceptualisation of PSS solutions are limited. Furthermore, research approaches are called for, which use empirical evidence from cross-case and longitudinal studies within the capital goods sector. Bridging the two research fields of PSS and Business Innovation & Management, has a potential for a novel research approach.

1.2 The Danish Maritime industry – industrial case

The industrial research foundation for this thesis involves ten companies from the maritime industry branch in Denmark. The coverage of a whole industry branch presents an opportunity to bring a strengthened understanding to the research field by investigating the branch and exploring the complexities and challenges in the transition to offering integrated product/service-systems within the capital goods sector, with focus on the ecosystem perspectives. Characterising the market of the industry branch brings unique empirical data on which the research project is staged and built upon. Maritime component manufactures are experiencing a growing demand from customers, with respect to after-sales service. In this context, the business opportunity to become more systematic about the integrated product/service development activities of the company has been identified in the industry. The Danish shipbuilding industry has traditionally focused on delivering products to its customers, based on the longevity and high technical/functional qualities of their physical artefacts. However, as with most established industries, the continuing market globalisation in the shipbuilding industry both opens opportunities, in terms of a rising number of potential customers, and represents threats, due to the growing number of competitors worldwide.

1.3 The innovation consortium: PROTEUS

The research project presented in this thesis has been part of a larger research project, named **PROTEUS** (**PRO**duct/service-system **T**ools for **E**nsuring **U**ser-oriented **S**ervice). PROTEUS was an innovation consortium that took a concentrated and deep focus on developing new knowledge about how after-sales service can be effectively integrated into product and business development, so as to become a source of revenue rather than a cost to the providing company. The innovation consortium ran from January 2010-December 2013 and was co-funded by the Danish Agency for Science, Technology, and Innovation (DASTI), the Danish Maritime Foundation (DDMF) and The Technical University of Denmark (DTU). The innovation consortium sought to investigate and implement product/service-system strategies at a number of levels in the participating companies and to make these insights generic towards the end of the project.

1.4 Research goals, objective, scope, and questions

This section will elaborate on the goals, objective, scope and delimitation, and the research questions guiding the research.

1.4.1 Research scope and delimitation

The industrial foundation for the innovation consortium concerned B2B companies, representing an industry within a high-value capital equipment branch, with a high installed base. The industrial foundation included ten maritime companies, which were not direct competitors, but which did have a few cases of competing product or service groups between the companies. None of the companies represented world-class best-practice, as is observed in other industries like for example Rolls Royce and their performance based “Power-by-the-hour” business model.

The aim of the consortium was to support the ten participating maritime component supplier companies in their transition towards a more integrated product/service-oriented business, by means of an action research approach. This thesis builds its results on the research carried out via an approach, where companies were identified according to their potential to successfully establish, operate and succeed at strengthened network constellations within their value chain, towards the aim of creating successfully co-develop and novel PSS solutions. The two companies identified for this in-depth study were MAN PrimeServ Frederikshavn and Alfa Laval Aalborg. A comparative case study was the main instrument by which the empirical research insights were elicited.

1.4.2 Research goals

- To strengthen the competitiveness of Danish maritime supplier companies, by supporting them in their transition towards integrated product/service oriented business (empirical specific).
- To understand the potential of industrial value network constellations for the strengthening of PSS conceptualisation (empirical generic).
- To contribute to theoretical knowledge about how network-oriented product development and PSS theory can be assessed and developed in combination with each other (theoretical).

1.4.3 Research objectives

- To develop a theoretical foundation for PSS development, with a particular focus on the perspectives from the PSS dimension ecosystem (actor network).
- To carry out a comprehensive empirical study across a whole industry sector, which is in transition from product to product/service-system oriented business.
- To derive and verify a normative framework for combined network-oriented PSS development based on theoretical and empirical studies.

1.4.4 Research questions

The research was guided by three overall research questions, which are sub-divided into guiding research activities, studied and answered throughout the thesis.

- *RQ1:* Through what terms and models can PSS offerings be described in order to support their successful synthesis?
- *RQ2:* How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?
- *RQ3:* How can a PSS conceptualisation activity allow an inherent network approach for co-development of PSS design?

To place the research questions in a context a *Reference Model* was created, which illustrated the context within which the research questions were placed. The research goal was defined based on this model and the model was created on the basis of the first two steps of the research design strategy, namely the criteria phase, where the literature review was carried out, together with interviews with industry and key researchers.

1.4.5 Audience

The research findings presented in this thesis are particularly intended for an audience interested in one of the following topics: PSS development; engineering design and conceptualisation; innovation strategies; network paradigm 'network based frameworks'; and sustainability. As the research is built on a thorough literature academic and industrial literature review of how to detail and elaborate PSS and its various dimensions and perspectives, the theoretical foundation of the thesis provides an in-depth description of the different dimensions of PSS. The focus in this research project is on the ecosystem dimension of PSS, for which reason a comprehensive literature study is presented, where state-of-the-art within PSS and servitisation literature are elaborated, paying particular attention to the ecosystem perspectives. Furthermore extant to this research field is the introduction of new tools and knowledge from business, marketing and innovation literature into the field of PSS, which is also studied and contributed to within this thesis.

Researchers interested in action research might also find the research approach interesting, due to the choice of research design and the methods adopted in the research project. The fact that this research project took place within an innovation consortium of ten participating companies and a research team of seven key researchers, makes the consideration of the research design and the research methods interesting to learn about.

For companies and organisations within the maritime industry, the thesis presents a large descriptive study of the industry, detailing challenges and possibilities for the industry (seen from a supplier perspective) to move towards are more integrated product/service-oriented business. An industry specific PSS offering typology is developed, which might serve as inspiration for the branch. The PSS tools created within the thesis are normative and tested, so as to be ready to be used by industrial practitioners.

For other (than maritime) industrial practitioners interested in PSS and seeking new tools and methods, the thesis brings insights into PSS development with a focus on network-based models, and presents various tools to use in conceptualisation and development of PSS.

1.4.6 Thesis Structure

This section will provide an overview of the disposition of the thesis.

1. Introduction: Introduces the research object and motivation behind the research project. Furthermore the literature gaps are presented.

2. Theoretical foundation: The main part of the literature foundation is presented in this chapter, divided into three main areas: PSS state-of-the–art; PSS from an Ecosystem perspective; and PSS and inter-organisational urgency.

3. Research approach: This chapter gives an overview of and argumentation for the different choices of the research design. The research stages are elaborated one by one, detailing the aim, empirical base and research methods.

4. Industrial research context: This chapter introduces the industrial empirical foundation of the research project, a general introduction of the industry and a detailed description of the two in-depth single case studies.

5. From a PSS offerings typology to PSS tools: This chapter presents a literature study on PSS offerings typology, together with a detailed description of the PROTEUS companies' current level of service offerings. Finalising with the development and presentation of two normative PSS tools.

6. PSS ecosystem conceptualisation: This chapter describe the third PSS tool. A set of six PSS Ecosystem Characteristics are presented by elaborating each of these in connection with the PSS phenomena.

7. Research evaluation: Presents an evaluation of the comparative case study, by presenting the actual support evaluated. The evaluation uses a unique analytical generalisation approach, by applying a new concept the PSS CE, a code and a set of coding rules.

8. Discussion and conclusion: Reflection, discussion and conclusion, by detailing research validity, limitations, core research contributions and finalised stating areas of future research.

2.

Theoretical foundation

2. Theoretical foundation

This chapter describes the theoretical foundation of the research project, which covers a broad range of research fields. PSS in itself is a multidisciplinary research topic, and with a particular focus on ecosystem and inter-organisational relationships, the literature review includes a variety of research fields, from product development to business management. The chapter uncovers the theoretical focus on the network perspectives of PSS and the need for changed relationships, when moving from a product-oriented business towards a more service-oriented business.

This chapter will give an overview of state-of-the-art PSS research, and a description of how the field has evolved, plus which trends have been observed in the field. This is followed by an in-depth review of the research contributions describing the PSS dimensions, by elaborating on four dimensions which have guided the research in this project, namely the: Ecosystem; Offering Life Cycle; User Activity Cycle; and Value Proposition. These dimensions are discussed and reflected on by using various research streams within the field of PSS. The second part of the literature foundation is the PSS literature focusing on ecosystem perspectives, which is presented and summarised. The third part of the literature foundation presents a focus on PSS and inter-organisational relations, elaborating on the trend towards consolidating to a multi-stakeholder approach.

2.1 Theoretical state-of-the-art for PSS development

Product/Service-Systems (PSS) is a concept that is still in its formative stages; there is no commonly accepted definition of this, and there is a wide array of literature embracing the concept of PSS within many different research fields. PSS therefore has many related terms, which in the design research community spans *industrial solutions* (Foote et al. 2001), *functional (total care) products* (Alonso-Rasgado et al. 2004) and *service engineering (Tomiyama 2001)*. Together with the many terms, comes the diverse description of what is understood by a PSS. A widely used description is by Goedkoop et al. (1999) "*a marketable set of products and services jointly fulfilling a user's need*." This was expanded by a reinterpretation by Mont (2004), to include the inherent ability of a PSS to achieve environmentally sustainable businesses, as the economic objective she argues is to create the highest possible use value for the longest possible time, whilst consuming as few material resources and energy as possible. Mont states that a PSS is "*a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and has a lower environmental impact than traditional business models*" Mont (2004).

The initial ideas behind PSS were laid out within the field of sustainability and environmental concerns, as a means to reach lower environmental impact than was possible with traditional transactional business models, seen to perpetuate material consumption. PSS is linked to closed-loop systems, extension of product life, and offering through-life services to prolong product life, such as upgrading and remanufacturing. The notion of the *performance economy* was coined by Stahel (2010) in which an industry adopts the above mentioned strategies, as reuse and service-life extension to reduce waste, with the aim of decoupling wealth from resource consumption. In Table 1, the differences between selling performance and selling products are described. The currently popular term "*circular economy*" is based on the underlying philosophy behind the performance economy, also referred to by (Stahel 2010) as the "*closed loop economy*", plus similar ideas at the time. This new vision was one of an economy in loops. Instead of traditional linear industrial models, with their focus on "take, make, dispose," the new vision was an approach to change the "*cradle to grave*" paradigm into "*cradle to cradle*." The Ellen MacArthur Foundation was founded on this philosophy and was established in 2010 with the aim of accelerating the transition towards a circular economy. Collaboration between the Ellen MacArthur Foundation and McKinsey & Company resulted in the report *Towards the Circular Economy*, launched in 2012. In this report, the authors present an analysis made across a set of case studies within manufacturing companies, showing that the industrial sector could realise net material cost savings worth up to $340-630 billion per year in the EU alone, towards 2025, by pursuing new strategies within product development, such as those of remanufacturing and refurbishment (*Towards the Circular Economy* 2013). As a non-linear industrial system, a closed loop system requires different relations within the value-chain; it is implicit in the term that the sequential value-chain is not suitable for this type of economy. It requires new collaborative structures to be able to reuse and make efficient use of materials and resources. A focus on resources and energy alone is not enough. A focus on societal structure, culture, infrastructures, and on information and knowledge sharing is just as, if not more important, to change the consumption patterns.

The research field of PSS strives to bring new development tools to manufacturing companies, in order to support the necessary transition to reach the vision of an economy, which does not compromise natural resources.

Table 1: The difference between selling performance and selling products, adapted from (Tan 2010) and (Stahel 2001)

Sale of a product (industrial economy)	Sale of a performance (service economy)
The object of the sale is a product	The object of sale is performance, customer satisfaction, the result
The seller is liable for the manufacturing quality (defects)	The seller is liable for the quality of the performance usefulness)
Payment is due at the transfer of property rights (an "as-is, where-is" principle)	Payment is due pro rata, if and when the performance is delivered (a "no-fun, no-money" principle)
Work can be produced centrally or globally (production); products can be stored, re-sold, exchanged	Work must be produced in situ (service), around the clock, no storage or exchange is possible
Property rights and liability are transferred to the buyer	Property rights and liability remain with the (fleet) manager
Advantages for the buyer: - Right to a possible increase in value - Status value as when buying performance	*Advantages for the user:* - High flexibility in utilisation - Little own knowledge necessary - Cost guarantee per unit of performance - Zero risk - Status symbol as when buying product
Disadvantages for the buyer: - Zero flexibility in utilisation - Own knowledge necessary (e.g. driver's license) - No cost guarantee - Full risk for operation and disposal	*Disadvantages for the user:* - No right to a possible increase in value
Marketing strategy – publicity, sponsoring	Marketing strategy – customer service
Central notion of value: high short-term exchange value at the point of sale	Central notion of value: constant utilisation value over long-term utilisation period

Changing business strategy from a product-oriented business to an integrated product/service-oriented business is seen in a variety of different industries. An example of such is Man Truck & Bus, which traditionally merely sold products (trucks and busses) but transitioned its business to be able to sell performance (transport solutions). Table 1 displays a set of examples that illustrate the shifts in value creation, moving away from the product, to offering a performance by a package of different products and services.

PSS entails a shift of business focus, from:

- Business based on *value creation through the transfer of product ownership and –responsibility* to…
- …business based on *value creation through the support and delivery of a service for a product, for the whole of its lifetime*.

Table 2: Examples of PSS in industry after (Tan 2010)

Company	From products…	…to services and total solutions
MAN Truck & Bus	Bus & Trucks	*"Transport solutions"* – training, asset management, leasing, rental financial services
Danfoss	Refrigeration controls and sensors	*"Cooling for food retail"* – design and specification, system integration, monitoring and reporting, energy management, condition based maintenance etc.
BASF	Paint	*"Chemical management services"* - quality painted surfaces
IBM	Computer hardware	Business and software consulting
Rolls Royce	Aircraft engines	*"power-by-the-hour"* fixed fee maintenance back-up service, condition monitoring, predictive maintenance, parts life management.
Xerox	Photocopying machines	*"Document services"* – leasing, maintenance equipment monitoring, paper and toner supply, document and data management etc.

That a company offers services is not a new phenomenon. This dates back several decades (Schmenner 2009), as manufacturing companies have often delivered services, such as sales and installation. Levitt (1972) went so far as to claim that "everybody is in service" and also pointed to the fact that the taxonomy used for services did not cover the whole service spectrum and argued that a focus should also be on product related services supplied by the manufacturing company.

2.1.1 Motivation and possibilities for a service-oriented business

The reason behind the increased interest in service-oriented business can vary from company to company, but in general increased global competition and shortened development cycles affect all manufacturing companies. The following threats are identified and listed by (Tan 2010):

- *Commoditisation of products* diminishes profit margin and bring a fierce price competition, even for high-tech products.
- *Saturation of markets and a high installed base*; the amount of new sales decrease.

- *Greater responsibility of products*; pressured by new state or global reaching regulation. Quality issues late in the product life can also be costly both money and reputation wise.
- *Proliferation of new products* increases competition and shortens sales cycles.
- *Financial crisis* reduces new product purchases.

By moving towards a service-oriented business, manufacturing companies can enter a whole different set of revenue streams and value creation activities, with many new business opportunities as listed below, based on (Tan 2010; Vandermerwe 2000; Mont 2004):

- *Increased profit margins*; in services, exploiting “downstream activities,” new ways of profit generation.
- *Diversity*; differentiating by offering a whole portfolio of product and service offerings.
- *Key focus on core activities*; outsourcing non-value adding activities to partners and external stakeholders, realising resources to core business activities.
- *System utility*; reducing downtime and failure of equipment, reducing resources spent on maintenance, increase customer satisfaction.
- *Longevity;* a new and long-term relationship with mutual dependency and with access to and possibility for long-term planning and forecasts.
- *Stability*; entering a contract or long-term partnership to bring a stable source of revenue.
- *Collaboration*; increased intensity of communication between stakeholders in the system (e.g. between manufacture and user leading to better development and value creation), creates simple and easy operation of complex systems.
- *Customisation*; from mass production to easy mass customisation close collaboration, and the new rapid development in communication technologies also allows proactive and preventive maintenance.
- *Bundled value proposition*; articulation of the results that the customer wants, selling and maintaining packages bring efficiency.
- *Bridge new inventions and upgrades*; introduction of new technology improves new sales and system quality.

- *Resource efficiency*; closed loop in materials, by take-back systems and the activities such as remanufacturing and refurbishing bring down material cost.

A product accounts for a maximum of 25% of the total price that consumers pay during their ownership of it (Mont 2004; Stahel 2010).

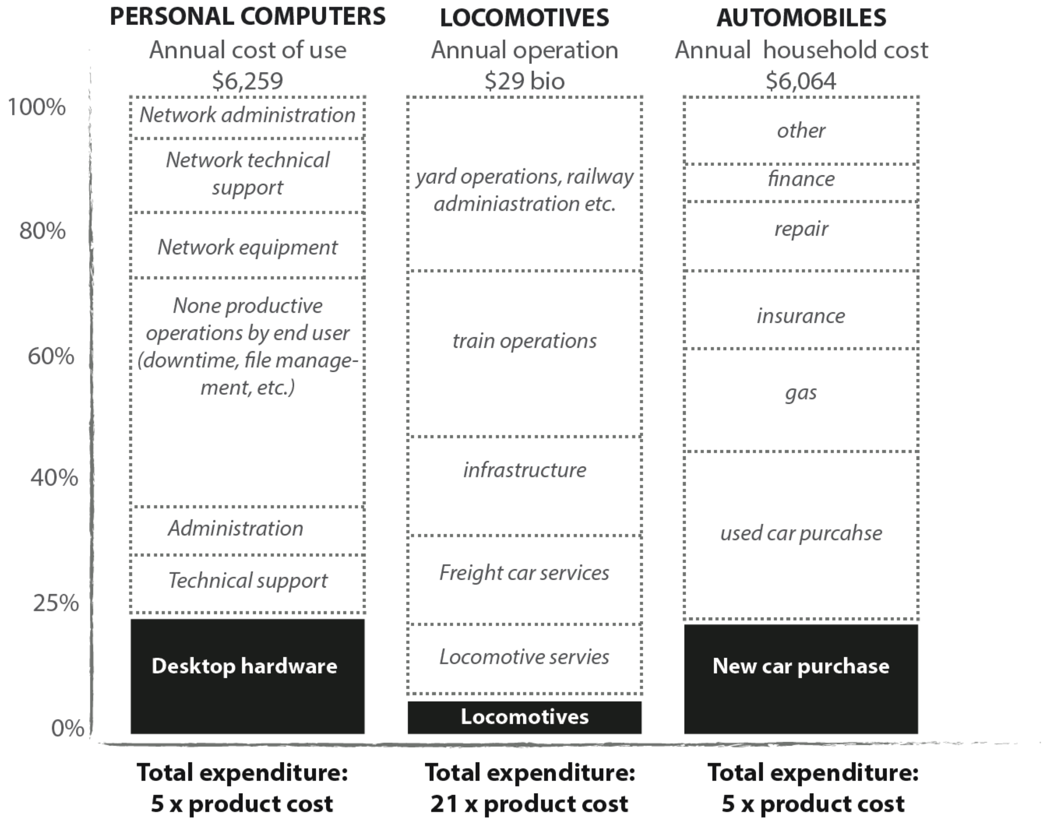


Figure 1: The purchase cost of the product only accounts for a fraction of the overall revenues. Adapted from (Wise and Baumgartner 1999)

The product purchased only accounts for a small amount of the total cost of ownership, and offering services throughout the entire product life cycle holds a potential for new revenue streams and profits for manufacturing companies (Wise and Baumgartner 1999).

Not only do new revenue streams become available but also a shift towards a more efficient business strategy becomes a possibility, with the change towards an integrated product/service-oriented business, which stimulates manufacturing companies to concentrate on core activities and outsource, or to enter alliances and partnerships regarding non-core activities, thereby improving the overall business. A number of factors and conditions must be taken into account before a manufacturing company selects and attempts a service strategy. Wise and Baumgartner (1999) present nine metrics for companies to assess and quantify the attractiveness of a potential service-oriented business, in a set of three different focus areas: i) attractiveness of downstream opportunity; ii) importance of customer relationships; and iii) power of distribution channel.

Through an investigation of Fortune 1000 companies, 78% of the companies interviewed experienced an increase in focus with "customer solution" (performance based PSS), not including a reflection on whether it generated increased profit, but merely that they experienced the shift (Gulati and Kletter 2005; Tuli et al. 2007).

2.1.2 Four dimensions of current PSS research

Within the PSS research, different dimensions have been observed as important for the PSS research focus: (Matzen and McAloone 2006; McAloone et al. 2010a):

- *PSS as a potential benefit*: A theoretical understanding of the opportunities inherent in PSS approaches to business, exploring and explaining opportunity parameters pointing towards, e.g., the dematerialisation of offerings, optimisation of performance or consumption.
- *PSS as an augmented product development theory*: Theoretical understanding of the phenomenon of combined product and service offerings, exploring and explaining the organisational development and design processes.
- *PSS as a strategy*: Prescriptive research to enable companies and larger networks to manage, deliver, and operate PSS solutions.
- *PSS as a mental mindset (design tools)*: Prescriptive research to identify and take advantage of the above-mentioned by development and implementation of new tools and models to aid the development process in conceptualisation and communication of PSS solutions.

The above areas of research almost match Tan's three levels of PSS design (Tan 2010), which after slight modification are the three levels of PSS that define how PSS is understood for the purpose of this thesis. The levels are as follows:

- *PSS solution*: a value proposition - a system of integrated product and services by continuous and mutually dependent development and operation by a network of stakeholders.
- *PSS development*: the activities constituting the development task involving stakeholders broadly from the network and crossing multiple levels of operation.

- *PSS approaches*: the approach required for companies to coordinate activities, relations, and competencies in the network to reach the desired business strategy.

2.1.3 Product/Service-System as a societal strategy for sustainability

The idea behind PSS as a concept originated in the 1970s with a focus on sustainability, environmental design, and close loop systems. The report (1976) and later published book (1981) by Stahel & Reday-Mulvey entitled *Jobs For Tomorrow – The Potential For Substituting Manpower For Energy* introduced one of the first solutions to overconsumption and exploitation of global resources (in combination with societal challenges on unemployment), presenting the *service economy* as an alternative to the *industrial economy* (Matzen 2009). Here, focus was on prolongation of product life cycles through services such as maintenance, upgrading, and remanufacturing (Stahel 2010). Dematerialisation was an integrated part of this new industrial strategy, which is still the backbone of many of the PSS strategies, with examples such as "System change" (Goedkoop et al. 1999) and "Revalorisation services" (Mont 2002) substituting products with services. Another important seed for PSS field was the initiative within the United Nations Environment Programme (UNEP) with continuous efforts aimed at environmental improvements and their World Commission on Environment and Development (WCED). In beginning of the 1980's, the Brundtland report was launched and cited ever since as the most broadly accepted definition of sustainability:

"... A sustainable development can be defined as a development that satisfies the needs of today without compromising the ability of future generations to meet their needs . . ." [Brundtland 1987].

Together with the proclamation by many academics, of PSS being a key contributor to the new century's sustainability strategy, a critical view has also emerged, regarding the actual goodness of dematerialisation strategies. This criticism is supported by the introduction of a discussion about *rebound effects*, where unforeseen effects and changes in the system caused by the PSS solution, may ultimately eliminate the intended gain (Manzini and Vezzoli 2002), or even have the opposite to the desired effect, inadvertently encouraging overconsumption (Tukker 2004; Behrendt 2003). This was also one of the observations in the PhD project of Mont (2004), with the question and title: "*Product/Service-Systems: Panacea or Myth?*".

As the focus has since developed to merged together with business strategies aiming at new economic potential from PSS (Tan 2010; Wise and Baumgartner 1999; Mont 2004), this is the main explanation as to why the field of PSS can be said to have two simultaneous tracks in research: i) PSS from an environmental perspective; and ii) PSS from a business perspective (Tan 2010).

Many different research streams over the years

Since PSS's origin in the 1970s, many different terms have been developed that have large denominators in their concepts, but which are rooted in different research fields, such as engineering design and pure business literature. The research presented in this thesis has used theoretical concepts and empirical findings from all the fields below, which will be presented throughout the thesis. The list below contains examples of the most dominant work(s) connected to each term or theme:

- Eco-efficient services (Behrendt 2003)
- Servicising (White et al. 1999)
- Service engineering (Tomiyama 2001; Sakao and Shimomura 2006) [Shimomura, Sakao 2006]
- Product Service Systems (Goedkoop et al. 1999)
- Functional sales (Mont 2001; Lindahl et al. 2006)
- Functional products (Alonso-Rasgado et al. 2004; Markeset and Kumar 2005)
- Solution-oriented Partnership (Manzini et al. 2004)
- Servitisation (Baines et al. 2009a; Vandermerwe and Rada 1988)
- Industrial Product Service systems (Roy et al. 2013)
- Integrated Solutions (Brady et al. 2005; Davies 2004)
- Customer solutions (Johansson et al. 2003; Sawhney 2006)
- Service science (Chesbrough and Spohrer 2006)

In a state-of-the-art literature review by Boehm and Thomas (2013) a review of 265 articles indicated that within three fields, information systems, business management and engineering design, the perspectives of these areas in literature were different. Figure 2 illustrates the frequency of perspectives taken within three overall areas: Engineering and Design has perspectives not surprisingly in a Design and Sustainability view, but also in a Strategic and Business level view. This thesis can be argued to strengthen the combination of Engineering Design and Business Management, where the perspectives of marketing, organisational, and innovation views will be strengthened.

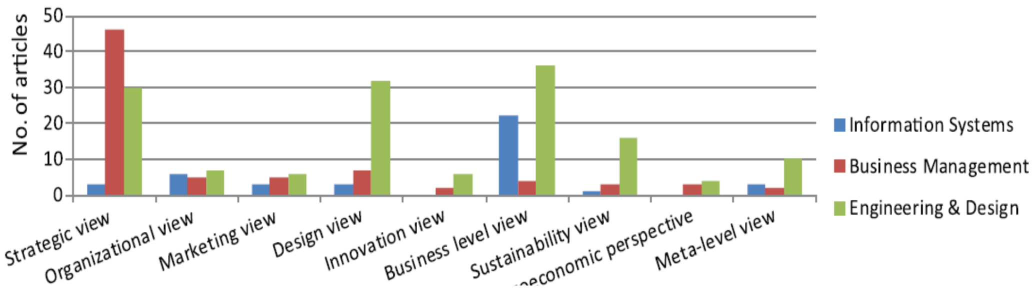


Figure 2: Frequency of perspectives in literature (Boehm and Thomas 2013)

2.1.4 From conceptual to prescriptive research studies

During the expansion of the PSS research field, various concepts have been presented, and the terminology within the community has grown accordingly. The consistency of the usage of the different concepts and terms for describing these has likewise worsened and yields for convergence (Tukker 2013; Park et al. 2012). As the field is fairly new (origin of PSS in Europe early 1970s), particularly papers focusing on the conceptual contents of PSS have been manifold. As bibliographical reference software has become smarter and access to online references broader, the research field has recently seen expanded literature reviews within the field, largely approached through a quantitative structured approach, for example in the latest large state-of-the-art reviews by (Tukker 2013; Boehm and Thomas 2013). Although such contributions argue that they are aiming at convergence within the field, one can argue whether such an approach is the right way to achieve such; the definition of PSS put forward by Boehm and Thomas (2013), does not differ greatly from that of Tukker and Tischner in 2006 (Tukker and Tischner 2006b).

A Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value (Boehm and Thomas 2013)

Figure 3 illustrates that prescriptive research studies have been of little focus. Much focus has been placed on conceptual principles and theoretical propositions (Mont 2004), elaborated from Hockerts & Weaver (2002). Despite this, the Journal of Cleaner Production has had three special issues on PSS (Tukker 2013). Mont concludes that more focus is needed on prescriptive research studies.

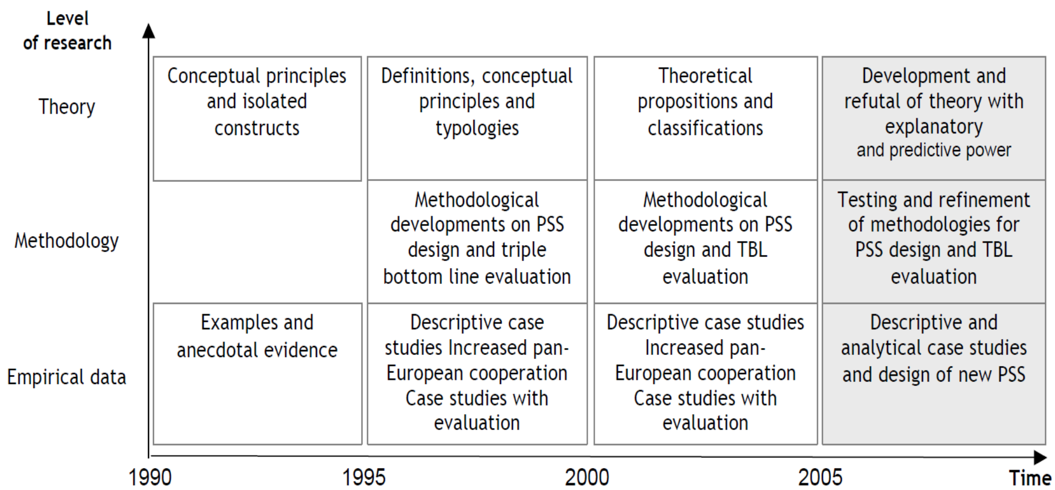


Figure 3: Development stages in PSS after Mont (2004)

2.1.5 No need to distinguish between products and services

A common denominator in the literature studies was the discussion of distinguishing services from goods, which is not a desirable objective anymore (Pawar et al. 2009; Corrêa et al. 2007; Tan 2010). Products and services are always bundled together (Normann and Ramirez 1993). The widely used IHIP: Intangibility, heterogeneity, inseparability and perishability (Parasuraman et al. 1985) is no longer useful (Vargo and Lusch 2004). Manufacturing and service integration is described as dating back in history more than 150 years (Schmenner 2009). This is simple because companies have made vertical integration (not just downstream but also backwards) to lock out new competitors. This can be supported by the belief that no products can be delivered or used without usage of service, and opposite (Baines et al. 2007; Goedkoop et al. 1999). Across many authors, it is found that distinguishing between services and products is not needed. Literature has previously dealt with how to describe products and services and how to distinguish between them. Tan (2010) describes that offering a specific value proposition, can be reached in different ways by viewing product and services as separate value propositions and therefore alternatives; they are value-creating components that together can aim to fulfil certain needs, through different constellations (Tan 2010).

2.1.6 Need for tools for industrial practitioners

Within the latest PSS literature, many different research areas point out the need for more research, among these are the network perspectives of a PSS (elaborated later in this chapter), but a large focus is on the need for methods and tools to develop and evaluate PSS. *"More research is needed to support companies to successfully develop tightly coupled service- or use-oriented PSS"* (Sakao 2009). Those that have been developed are lacking validation "*However whilst a range of tools and methodologies exist for designing PSS, there is a lack of evidence to demonstrate whether they represent industrial practice"* (Baines et al. 2007). Tan (2010, 15) also opens his thesis describing that there is nothing new in companies offering products and services together, but there is a need for the offerings to mutually support each other. *"... When products and services are tightly coupled, products and services must be designed concurrently . . ."* (Alonso-Rasgado et al. 2004; Kimita et al. 2009). Figure 4 illustrates an overview of a large literature study of 58 papers from the 1970s until 2009 by Baines et al. (2009a), focusing on servitisation literature not including the PSS community. It is interesting to notice that the overview of key themes only includes few papers covering conceptualisation and development frameworks and tools for practitioners to use (theme 1 and 2 on Figure 4).

A few of the latest literature studies like (Lightfoot et al. 2013; Tukker 2013; Boehm and Thomas 2013) take a more quantitative approach to look for trends in the different overlapping fields. The literature study by Hou and Neely (2013) also takes a quantitative approach within a specific key theme, namely barriers to servitisation. This is from the perspective of papers with the terms; servitization, servitisation, servicizing, and servicising.

Servitization literature – key themes (based on 58 papers reviewed in detail)	Number of papers covering the theme	Percentage of total papers
1 General concept and definition	8	14
2 Evolution of the service orientation in manufacturing	7	12
3 Classification of services	32	55
4 Classification of corporate approaches to sevitization	7	12
5 Drivers of servitization	35	60
6 Factors that undermine the adoption of service strategies and methods for go/no-go decisions	16	28
7 Challenges in moving into services	21	36
8 Guidelines and methods for successful implementation of service strategies	39	67
9 Case studies		
(a) Deductive	27	47
(b) Inductive	23	40
10 Customer value	18	31
11 Service marketing	14	24
12 Service design	13	22
13 Organisational structure	27	47
14 Human factors	11	19
15 Technology support	12	21

Figure 4: Servitization literature and key themes (Baines 2009a)

2.2 The PSS design object and conceptualisation used in this thesis

Consistency in the *definition* of the dimensions as described above and the *aim* and *usage* of these do not exist in the community yet. Tan (2010, 172), defines a set of four PSS dimensions: Actor Network; Customer Activity Cycle; Product Life Phase; and Value Proposition, which should guide the PSS development by aiding the developer in which perspectives to take, whether synthesising existing systems or developing new ones. The dimensions are further understood as constituting a meta-model for conceptualisation. The aim of the dimensions is to constitute a set of design objects for the PSS development team, as the design object of a PSS differs from that of a traditional product- or service-oriented company (Morelli 2006; Manzini et al. 2004; Tan 2010).

The value proposition of a PSS (which, for example, could be "*guaranteed performance of a system*") indicates the shift in what influences the perceived value of the user, and hereby also describes the perspectives that need to be included in a PSS design object. Or as McAloone (2010) describes it, the so-called *boundary conditions for a new type of design task*, which refers to the PSS development activity and what kind of perspectives are needed. As the value proposition in a PSS may alter the responsibility and ownership, from customer to supplier (which could be the case of e.g. "*guaranteed performance of a system to a fixed price*"), the design object expands in time (McAloone 2011) for which reason insight into the performance of the product and the way it is used becomes vital. With a focus on the life cycle perspective, particularly two life cycles: the product(s) life phases; and the activity cycle of the user(s) (McAloone and Tan 2005) are presented. The customer's value perception changes from value-in-exchange to value-in-use (Vargo et al. 2008; Martinez et al. 2011b; Baines et al. 2007). The PSS solution needs continuous maintenance throughout the product life cycle and new relations need to be established. This is due to the fact that new interventions need to occur, for which reason the ecosystem (the value network) becomes important. Traditional Customer Relationship Management broadens, to become Relationship Management. A product can be viewed in a PSS as being augmented with respect to time, infrastructure, value, and artefact considerations (McAloone et al. 2010a). In defining the different dimensions of PSS, it is important to take care to also describe and define the relationships between the dimensions, so as to ensure that there is coverage of how they are all causally related. In the framework of (Mont 2004), the description of how the PSS dimensions are causally related is omitted.

Throughout the PROTEUS project, a deeper understanding of how to define the PSS design objects has been gained and presented to industry through the PROTEUS workbook series #4: PSS Tools (Finken et al. 2013) The dimensions presented by Tan (2009) have been slightly altered and the design objective of a PSS has in this research project followed *four* different conceptual dimensions, with each their own design perspectives. The dimensions are partly described through new terminology matching the development in literature, with a slightly different constellation of perspectives in each dimension compared to Tan's, the new dimensions are:

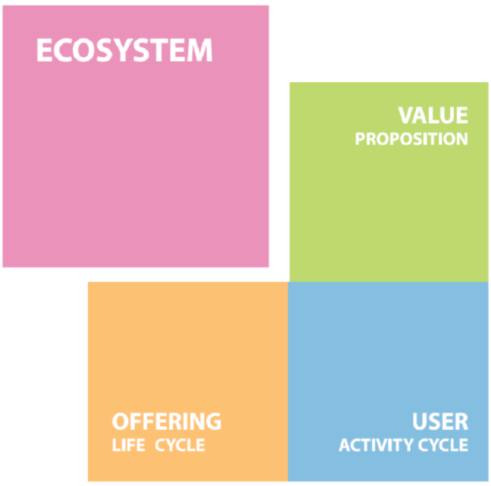


Figure 5: The four PSS dimensions after (Finken et al. 2013)

The following four sections will elaborate on the four PSS dimensions, as to position the approached PSS design object, namely the ecosystem. This will be elaborated in detail in this chapter.

2.2.1 Value proposition

A PSS can be understood and detailed through the value proposition that is offered to the customer (Tan 2010). The value proposition consists of a product and service combination, aims at meeting the exact needs of the customer and at generating benefits that have the highest possible perceived value of the involved stakeholders. The value proposition is a means to express the benefits that the customer can expect; it is about a proposal and a promise to the intended user. One instantiation of a value proposition, frequently used in the Life Cycle Assessment field, is the definition of the so-called functional unit (Stahel (1997), defined as a quantified outcome (performance) of the product, over a specified time period. The value proposition can be seen as a context-specific way of expressing the aim of a PSS for a specific set of stakeholders, e.g. with the definition from Goedkoop et al. (1999): "*A marketable set of products and services, capable of jointly fulfilling a user's need*". The value proposition is defined as an implicit promise a company makes to its customers to deliver a particular combination of values (Martinez 2003). See also "Appendix A: Value proposition", for a comprehensive list of value propositions in PSS and their definitions.

Archetypical PSS can be viewed as constituting theoretically or conceptually ideal value propositions. The research field has been focusing on such PSS classifications since its establishment, as is charted by Goedkoop et al. (2009). Four different types were mentioned in categorising the Product-Service ratio. This categorisation does not reflect the value proposition but merely the way in which the value proposition is constructed. The most referenced categorisation of PSS is by Tukker et al. (2006), where three main categories are presented: *Product-oriented; Use-oriented; and Result-oriented* PSS, where sub-categories are listed within each, primarily differentiated by revenue mechanisms, which is also seen in the revenue scheme by Lele (1997). This categorisation approach has been widely accepted within the community but has also been a target for criticism, e.g. the large focus on payment as main source for value categorisation (Ostaeyen et al. 2013). Neely (2008) builds on Tukker et al.'s categorisation, by adding two new categorisations: *integration-oriented;* and *service-oriented PSS*. According to Neely, *integration-oriented PSS* focuses on system integration, e.g. through vertical integration downstream in the value chain (getting closer to the customer), which is complementary to one out of four integrated service solutions described by Davies et al. (2006) namely *System integration*. Ostaeyen et al. (2013)

expand the three categories by Tukker (2006) to cover six categories by re-naming *Result-oriented PSS* to *Performance-based PSS*, covering three sub-categories: *Solution-oriented*; *Effect-oriented;* and *Demand-oriented* PSS, and furthermore adding a new category of *Availability-based*. The performance based (Result-oriented) PSS, matches Roy's interpretation of this category (Roy and Cheruvu 2009), as this is referred to as *Capability-oriented contracting*, where Use-oriented is referred to as *Availability contracting*. As this clearly illustrates, the field has not yet reached any broad agreement regarding the main way in which to categorise PSS.

It is important to note that a company can have various value propositions with the same product, through different PSS strategies (business models). Windahl (2007b) believes that coexistence of business models takes place when offering PSS solutions and does not necessarily follow a linear continuum of change, from goods to services.

PSS offerings in combination can constitute a value proposition and different combinations can result in the same value proposition. This is seen in MAN Truck & Bus, for example, where the "*transport solution*" can be matched to any of the customer's needs through the company's large range of financial agreements, via car hire, rental and leasing – all of which consist of some mix of different PSS offerings present at the company. A similar situation can also be observed in the study by Phillips (2013), where four distinct value propositions were found within one case company: *asset, recovery, availability, and outcome-based* PSS. The fact that an organisation can hold all four value propositions might contradict much of the literature claiming the importance of the transition (the servitisation journey), representing separate evolutionary stages from product- to service-oriented company (Phillips et al. 2014). The value proposition corresponds directly to what is the *effect* in Tan´s (2010) framework. It is argued that the value proposition is perceived by the user, and that this is the effect the system has. Matzen (2009) presents the value proposition in the artefact domain, where, for example, an offer portfolio is suggested to manage all offerings (agreements, activities, and products).

Within the value proposition dimension of PSS a perspective of high importance is brought to the developer, as this defines the intended value creation within the PSS. The change from understanding value creation to be moved from value-in-exchange to value-in-use is one of the biggest challenges in transitioning from a product-oriented company to PSS-oriented business. The value proposition can act as a mental mindset for the involved stakeholders of what kind of KPI's would be suitable to aim for, in order to sustain the chosen value proposition. The fact that many companies face today is that value no longer lies in lowest purchase price (unit cost) but in predictive and lowest life cycle cost (whole life cost). A key point within the value proposition dimension of PSS is that value cannot be quantified and mirrored by product properties and evaluated by its utility. Instead it must be viewed as a strategy to continuously match the needs of the user, where value-in-use is co-created by the supplier and the customer (Ng et al. 2012) and is an outcome of all stakeholders involved in the system.

" ... Value under this logic [i.e. PSS], is no longer an inherent property of a unitary resource or offering, but rather the outcome from the relational enactment and interaction between the providers and receivers of an offering. In other words, value is created not in exchange but co-created in use or in context ... (Ng 2014)

A finally important point about value proposition in relation to PSS is captured in the above quote, which emphasises the change in value-logic within PSS. Many scholars in the research field state that value is not sequentially delivered from one company to another but is co-created iteratively between multiple stakeholders (Chandler and Vargo 2011; Ng et al. 2012; Lockett et al. 2011).

A PSS approach means a change in satisfiers of the customer, from value based on product sold (value-in-exchange) and the subsequent utility of the product, to one of function delivered (value-in-use), as perceived by the customer. It is a unique characteristic of PSS, to view the value creation in relation to the customer and the activities of the customer, when using and maintaining the product, all the way from first point of sale, through use and to disposal (Mørup 1993; Wise and Baumgartner 1999; McAloone and Andreasen 2002; Matzen and McAloone 2006; Tan et al. 2010). This insight is seen as opening a multitude of alternative channels through which to deliver value to the customer and fulfil customer need. The above-listed authors do not explicitly distinguish between an "offer" and a "value proposition". Matzen (2009) uses three domains to describe a PSS: *artefact system, activity system,* and *actor networks*. In Matzen's work, the value proposition is found within the artefact system, as this can be represented as a portfolio of offerings, comprising of the total capabilities and competencies connected to a certain technology that can be directed towards the customer. The various combinations of such capabilities and competencies compose the possible value propositions (Matzen 2009). Looking at Mont's (2004) framework, products and services are found directly as two separate elements out of four core elements that describe and conceptualise a PSS. Within Mont's work, the value proposition by Goedkoop (2009) is referred to, namely that a PSS is *"...a marketable set of products and services capable of jointly fulfilling a user's need".* Many of the descriptions do not describe different PSS proposals, but instead focus on cases where PSS causes the material ownership to move from customer to supplier, and where risk and responsibility is shared (to varying degrees) between supplier and customer. This is useful for the transition journey as it provides the PSS designer with an end goal – a state-of-the-art, advanced PSS. However, it is still important to be able to configure the different values that are connected to a value proposition. Such an effort is made by (Tan 2010), where he proposes a PSS morphological matrix to support the systematic conceptualisation of a PSS value proposition.

"... A product/service-system may consist of products, services, or their combinations. Products substituted by services are largely an ideal category, without many practical or consistent examples, because any service, even non-material per se, requires material or energy input ..." (Mont 2002).

The product and the service can be equally important for the fulfilment of the user's needs (Tan 2010; Matzen 2009; Goedkoop et al. 1999; Tukker and Tischner 2006b). The value proposition can consist of an integration of both products and services, bundled in packages (Corrêa et al. 2007); combinations of products and services (Tan 2010; Matzen 2009); in bundles (Vandermerwe and Rada 1988) (Sharma and Molloy 1999) (Kotler 2000); as integrated product and services (Davies 2004); or as a mix (Corrêa et al. 2007). Some authors interchangeably use multiple definitions from the above list. Within operations management, the term 'bundle' has been used in connection with the description of the shift in selling products to selling a selected group (the bundle) of products and services, often at a fixed price. Such an activity is a fine balance for a company because it is important to lock the customer into a relationship, but this can also bring negative side effects (e.g. mistrust or inflexibility). In fact, the contractual element and the careful description of the value proposition and the basic business model for delivering this, is what is seen as one of the largest challenges in PSS design, as this covers the question of who takes which risk and how easy it is to get out of the agreement, as Vandermerwe and Rada describe, below.

"... Bundles and systems are the same the system is the link between the different offerings, the value proposition is created within a system, which can be described by benefit bundles ... " (Vandermerwe and Rada 1988)

Describing the value proposition of a PSS, characteristics are used to accentuate the development of the manufacturing company's value propositions, as it begins to servitise. Starting with offering products, through offering bundled value propositions, to finally offering the performance, companies are described as transitioning from *traditional value propositions* to *solution-based value propositions* (Sharma and Molloy 1999). Furthermore the development from a value-in-sales to a value-in-use business mode is also well described (Baines et al. 2009b).

2.2.2 Offering Life Cycle

The *Offering Life Cycle* represents the continuous flow of products and services within the PSS. The offering life cycle emphasises the need for continuous delivery of services and products from which the promised outcome can be achieved. Also, the offering life cycle refers to the performance the "customer" gets and the supplier has committed to orchestrate, deliver and sustain. It is not dependent on one single product, but a system of products, services and other technologies that follow and support each life cycle stage of the main product to which the PSS is connected. The offering life cycle emphasises that it is important to focus on the product and service in more than merely the use phase, extending to multiple product life phases, including transport or disposal within any of the phases. Multiple stakeholders will be involved and these are dependent on the right information, having great influence on the quality and value of the system. In the work by Tan et al. (2006), two life cycles are presented instead of just one, where the customer activity cycle is included (Tan et al. 2006). This matches Mathieu's (2001a) approach, where services can support either the product (product-oriented view) or the customer. Matzen (2009) describes a PSS life cycle of customer relationship, via a graphical illustration of how the customer's activities are continuously supported by the supplier. Similarly, Matzen's representation shows not one but multiple product life phase systems, underlining the fact that within the "Artefact Domain", the Offering Life Cycle of the product might change by a replacement system (Matzen and Andreasen 2006). The concept of Recovery Loops (Olesen 1996) illustrates greatly how the material flow across the different life phases adds value. It also illustrates the benefits of orchestrating take-back systems and activating service-oriented competencies, for e.g. refurbishing, as material value is raised by reuse and closed loop systems. The concept of Cradle-to-Cradle (McDonough and Braungart 2002) can be argued to be a re-launch of the Closed loop economy and re-explained using new terminology. Using the life cycle as the design object originates from the Theory of Dispositions by (Olesen 1992), which itself emerges from ecodesign, where the notion of dispositional effects spanning across the whole product life cycle is a key element (Matzen 2009, 4). Buur and Andreasen (1989) investigate how the designer influences the resulting product properties and performance throughout the product's life, by visualising the mechanism of dispositions.

"... By a disposition we understand that part of a decision taken within one functional area which affects the type, content, efficiency or progress of activities within other functional areas." (Olesen 1992)

It can be said that the product life cycle becomes the design object within PSS (McAloone 2011). The product life cycle consists of all the different phases that a product goes through, from material extraction to use and disposal, and when designing, all phases must be taken into consideration (Olesen 1992). For some time now, the so-called *Product Life Gallery* method has been widely implemented in industry and academia, to provide a graphical overview of the product life cycle and environmental profile, where decisions and potential trade-offs regarding improvements can be made and considered (McAloone 2007). The offering life cycle corresponds to the view needed when carrying out *Life Cycle Costing*, where Wise & Baumgarther (1999) argue that a thorough analysis of the cost connected to maintain the system must become the platform upon which an evaluation is based. Such a platform can help to evaluate whether the supplier can take over responsibility for moving its business activities towards becoming an integrated product/service provider. Likewise, this exact overview is the information needed to change the mindset of the customer, from value-in-exchange to value-in-use.

This PSS dimension is represented in literature by a few different dimensions. Matzen (2009) describes Artefact System Domain, which corresponds to Tan's (2010) notion of Life Phase Systems. Matzen argues that value propositions are an integrated part of the service activities and are therefore inherent in the Artefact domain, whereas Tan (2009) uses the value proposition as the final resulting effect that the system produces.

A holistic view is often stated as a necessity for PSS development; taking a whole offering life cycle view can be one approach to achieve this. Tan (2010) presents a model detailing different service strategies and the corresponding development competencies needed, illustrating that for the throughout the offering life cycle new competencies might be needed, which in themselves will certainly require new business strategies. As an example, product durability and longevity in a PSS strategy will require unique competencies in the line of life cycle economical modelling.

This PhD thesis elaborates on the offering life cycle, what literature says about different service offerings, and what strategy can the supplying company take to move towards an integrated product/service-oriented business.

2.2.3 User Activity Cycle

PSS can be seen as a user-oriented innovation strategy, where user-centred and user-oriented design are key (Tan et al. 2009). By definition, PSS focuses on the user's needs, in order to be able to create the most suitable solution. From this perspective the important focus is on the on-going relationship with the customer, where support is continuously delivered or co-created (Matzen and McAloone 2006). To be able to create the right conditions within which the highest value can be received (perceived) by the customer/user, insight into needs, capabilities, and incentives becomes important. As this insight might best be found by understanding the user's activities, the user becomes the focal point for analysis. From this approach, it is possible to identify where and how to support the customer, by adding value (Vandermerwe 2000).

Within PSS, a product/system might pass many different customers and users. For this reason, Matzen and McAloone (2006) reworked Vandermerwe's original *Customer Activity Cycle* approach, to present the

Activity Modelling Cycle. A PSS is an integrated system of both product and services, where value is perceived by the user but might be co-created between multiple stakeholders in the system, which is why a focus on the network dimension is equally important. This dimension corresponds directly to Tan's (2010) view on Customer Activity Cycles, where the only difference is that it is dubbed *User Activity Cycle*, so as to emphasize that the system may have multiple users (e.g. in the maritime industry: second-hand shipowners vs. speculative shipowners) and that customer and end-user can have different incentives and needs (shipyard, shipowner, leasing liner company, final the crew, etc.). The notion of multiple potential *users* matches better the PSS paradigm. The *Actor system* (Actor network domain) dimension described by Matzen (2009) corresponds similarly to the User Activity Cycle dimension, where the focus is thus changed slightly, from a customer perspective to merely focusing on the importance of defining process steps and sequences of activities, which together constitute the PSS solution (Matzen 2009). Within the framework of Mont (2004) there is not one dimension for user focus or activity focus, but her framework of PSS dimensions also includes four extra PSS framework elements with sub-categories, including customer satisfaction, cognitive, and normative aspects of the PSS. Mathieu (Mathieu 2001a) distinguishes support within the system to be either support to the product or support to the customers.

There is great interconnectedness between the offering life cycle and the ecosystem, as pointed to in the above, but particularly as activities might often be "shared" in a co-creation activity, where customer's input by, for example, allowing access to performance data – giving opportunities for the supplier to forecast needs for service and proactively contact the customer.

2.2.4 Ecosystem

The ecosystem is the human-context and environment within which the PSS occurs and must perform and through which it will be developed, sustained, and evaluated (Mont 2004; Tan 2010; Windahl and Lakemond 2006; Matzen 2009). It is comprised of networks of stakeholders, which in combinations and through interactions constitute the surroundings of the PSS (Apitz 2013; Mougaard et al. 2012). When transitioning from a manufacturing company to a PSS-oriented company, the ecosystem structure changes (Mont 2002; Baines et al. 2011), meaning new relations between stakeholders are established (Mougaard et al. 2012; Martinez et al. 2010; Windahl and Lakemond 2006), new roles arise, and new stakeholders may be involved. As it only exists in the time the ecosystem will be in constant change (McAloone et al. 2010a; McAloone 2011). Stakeholders are embedded within networks through interconnected relationships that bring opportunities and constraints to their actions. According to the majority of scholars, a focus has been on the change in the relationship between supplier and customer, described as changing from transactional to relational (Martinez et al. 2010; Matthyssens and Vandenbempt 2008), from one point of contact (sales of product) to continuous contact, throughout the whole product life cycle (sales of performance).

The importance of customer relationship management is argued to be of high importance (Lockett et al. 2011; Brady et al. 2005). The focus of a PSS is therefore to continuously interact with the customer, in order to sustain and enhance the customer's perceived value of the system (Tan 2010; Tan et al. 2009). This relationship change can be viewed as a change from transactional, to relational, to interactional (Martinez et al. 2010), which implicitly describes the value proposition as created continuously in an on-going relationship through a range of different offerings, matching the actual need of the customer, where the latter mentioned is moving towards what can be called "integration with customers business" (Matthyssens and Vandenbempt 2008). This is described by many scholars and covers the phenomenon where new roles are taken and responsibilities are moved and shared in novel ways between stakeholders. The on-going relationship with the customer can take place between two or more stakeholders and new stakeholders may become part of the system (Mont 2004d). Within the ecosystem of a PSS, stakeholders can be found outside the "product chain". When PSS development starts with the needs of the customer and a definition of the function, the challenge is to find stakeholders who are in the best position to deliver the function to the customer. Sometimes the producer/manufacturer is not the best option, simply due to the distance and therefore the weakened or lost relations between the final consumers (Mont 2004; Wise and Baumgartner 1999).

Furthermore, as the PSS is dependent on many parameters in society, for example cultural behaviour and legislative changes (Mathieu 2001b), Johnstone et al. (2008) claim that the PSS strategy needs to be carefully aligned and defined with basis in the level of cultural changes needed. Mont claims that cultural behaviour is one of the major barriers for a wider implementation of PSS (Mont 2004) and also puts much focus on this by using two dimensions: i) Infrastructure and ii) Actor Network, to describe these influencing parameters of a PSS. She furthermore places additional emphasis on an *institutional framework* of three elements: i) normative; ii) cognitive; and iii) regulative. In a PSS, the value creation process is different than from a regular product-based business, as described earlier. Tan (2010) describes the value proposition to be the effect of the system, and within the service-dominant logic, scholars define a service to be perceived only when activated in some way. This is where the interconnectedness in the PSS ecosystem becomes interesting, as the value created can be seen as dependent on all stakeholders within the system and a collective approach can therefore be argued to be needed.

"... A PSS is a social construction, based on "attraction forces", which catalyse the participation of several partners. A PSS is the result of a value co-production process within such a partnership ..." (Annamalai et al. 2011)

The above quote frames perfectly the importance of the ecosystem in a PSS, as the result of any performance-based PSS is dependent on multiple stakeholders, and therefore the value-creation process is a shared task. With a shared value-creation process, a change in the economic system through which the companies generate profits is required. This can be achieved by, for example, charging the customer for function delivered rather than for product sold. This means that the revenue is generated through a set of activities (supporting the performance of the product) and not just one activity (purchase of the product). This also means that the revenue-generating activities may be shared between different companies and suppliers; i.e. a network of service suppliers. There are many descriptions of such service supply networks in the literature. (Davies et al. 2006) use three different strategies for approaching the need for new competencies. In relationships where profit sharing and risk sharing is present, a key need arises in protecting intellectual property and resource investments (Roy and Cheruvu 2009).

Furthermore, if the service activities can be covered by in-house capabilities, there will still be a change in relationship and a need for collaboration as a PSS demands an integrated product development strategy. It requires a changed organisational structure (Tan 2010). For example PSS sales lies not solely at the sales department but at the interface between the sales and after-sales department. Baines et al. (2011) describe this as *micro-vertical integration*. The same term describes integration within the product-chain. Brezet et al. (2001) describe the need for different areas of expertise as *product development needs engineering skills*, and *design of services needs competencies* and *insight into business management and strategies and service procedures*, which all are deeply rooted in the company organisational structure. By nature the PSS consists of multiple connected products, which creates a need for closer collaboration between suppliers. Matthyssens and Vandenbempt (2008) use the term "Technical application integration" to describe this. Also, the term *Integrated Product Service Systems* often refer to high technology systems, consisting of multiple sub-systems.

2.3 PSS from an ecosystem perspective

As just presented the PSS ecosystem structure changes, when moving from a product-oriented business towards an integrated product/service-oriented business. New roles arise and new relations are created (Mont

2004; Tan 2010; Windahl and Lakemond 2006). Researchers explicitly call out for more research within the changed external relationship:

- Examine value creating in a broader network surrounding customer and its key suppliers (Ulaga and Eggert 2006, 133).
- Additional research which includes all actors in the business network (Windahl and Lakemond 2006).
- Matzen (2009) claims that service-oriented product development should be prioritised in companies as *high level collaborative development activities* and points out that research is needed to investigate how this can be possible and how this can be anchored organisationally.
- Typically, products and services are only considered in one episode, regarding the customer, and not the entire customer value chain (Ravald and Grönroos 1996).

Some exemplary citations that state the need to focus on the ecosystem perspectives of a PSS include the following:

- *" ... It is important that the topics of supply networks are put in focus in PSS research ..."* (Lockett et al. 2011)
- "... *Real-life examples of integrated solutions are somewhat more difficult to find, especially when it comes to manufacturing firms in the capital goods sector ...* (Windahl 2007b)
- " ... *Theories dealing with inter-organisational issues may also be useful for the PSS field, since product life cycle is considered from supply chain and actor perspectives ..." (Mont 2004, 46)*
- "... *Customers and users represent valuable resources that can be actively employed in the development and delivery of PSS. However, methods and processes for how companies can effectively and efficiently manage the different roles and responsibilities when working together in broad actor networks are not well developed ..." (Tan 2010, 220)*

The two lists above clearly indicate that current research expresses the need for more focus on the ecosystem perspectives of PSS. The topic of this research project is to approach this gap, investigating how a PSS can be developed and operated, by ensuring the best possible ecosystem structure, to approach a PSS by what Manzini (1999) describes as *companies as flexible networks.*

2.3.1 Frameworks and tools focused on the PSS ecosystem dimension

This section will give an overview and reflection of existing frameworks, tools, and approaches with particular focus on the ecosystem dimension of PSS. This section therefore had the guiding activity investigating; what techniques exist to bring the ecosystem perspectives as an integrated part of the PSS solution space.

When conceptualising PSS, an understanding of the whole ecosystem of stakeholders is key to a successful PSS (Mont 2004; Tan 2010; Matzen 2009). Insights into needs, capabilities, motivations, challenges, and barriers of each stakeholder are vital for PSS conceptualisation and to be able to manage these on a long-term basis to sustain the PSS and stay competitive. Different methods for looking into the stakeholders of PSS have been presented, where the majority of these have been borrowed from other research disciplines. e.g. service design and social sciences, actually a myriad of stakeholder network mapping methods exist, but which all need a certain right 'resolution', mental mindset and integration within a PSS conceptualisation process, to be able to derive at the suitable level of insight to exploit and design the ecosystem of a PSS. Furthermore, designing a network by connectedness between social stakeholders is said to be not possible as this is autonomous and has a 'life on its own' (Tan 2010). Influencing the network and orchestrating it can be seen as a design activity (Manzini et al. 2004), and *company network capabilities*, 'ability to navigate, adapt to, and control the network' is seen as an asset on the same level as financial assets (Manzini et al. 2004; Ring and Van de Ven 1994). This is also described by Davies (2004), as business strategies and internal capabilities need to be closely combined with external resources, which is an important challenge for the companies to overcome:

"... for many firms, the biggest challenge will be developing the capabilities to integrate different pieces of a system provided increasingly by an external network of specialised component suppliers, subcontractors and service providers ..." (Davies 2004)p. 753)

Only a few frameworks combine strategic thinking connected to the ecosystem of the PSS, with examples like (Tan 2010; Matzen 2009; Mont 2004; Windahl and Lakemond 2006). The notion of a '*partnership-based business model approach'* is introduced by Matzen (2009). Here focus was put on the gradual alignment of business processes between customer and supplier, strongly or fully influenced by the technology platform or expertise at the supplying company. Based on the type of PSS solution, three different alignment strategies were suggested: i) operational; ii) dispositional; and iii) and strategic alignment. Strategic alignment was comparable with that of a strategic partnership, where the PSS can be seen as a “long-term business strategy based on value co-production amongst partners” (Manzini et al. 2004). This framework is not a process framework indicating what to do in the conceptualisation process, but is merely an approach to model the business approach and act as a conceptual understanding of different collaboration opportunities between supplier and customer. Another model also presented by Matzen and Andreasen (2006) termed ‘*PSS life cycle of customer relationships’* is an actual modelling technique, as well as it is a conceptual model of how the relationship between the customer and the supplier can be seen as a *relationship life cycle* as the relationship is continued through time by the supplier using the sequence of customer activities as a point of departure for any support offered. These two models are conceptual frameworks, both with focus on a single relationship, namely that of the supplier and the customer.

A framework developed by Tan (2010) named ‘*A Model for PSS development activities’* depicts the PSS development and illustrates how this is an intra-organisational task, which takes place on multiple levels within the organisation, whilst at the same time being an inter-organisational task, where the strategic assessment and planning exists on a top level called ‘business strategy’, where the primary partnering opportunities are investigated, initiated and maintained. “*Establishing and managing the actor network is crucial to enabling the PSS and its development to function*” (Tan 2010). Within the model, PSS development includes external stakeholders at all levels except one, which is the ‘portfolio level’ – the business and product planning, where the actual PSS conceptualisation takes places. This model compared to the ‘*partnership based business model approach’* focuses on the development task within the organisation, and illustrates how multiple external stakeholders are involved in the PSS development. The two models are not counter-expressive. One model focuses on the life cycle of the customer’s activities and how the alignment of the business process must take place, whilst the other focuses on the PSS development activities (internal and external) necessary to be able to do this.

It is also interesting to mention that certain notions of what changes when moving from sale of a product to sale of performance include the network change, as stated by Stahel (2001), who compares the *industrial economy* to the *service economy*. Another well-known table of changes during the transition is described by Nórlen (1999), where particular focus is placed on the changed interaction with the customer, where a limited relation with the customer is changed to a continuous relation by a ‘network’ of companies see table Table 3.

Table 3: Traditional sales vs. Functional sales - after Norlen 1999

Traditional sales	Functional sales
Producer's involvement is limited to warranty period. Over the life of the product support is provided by the organisation that has no relations with the producer.	Support from a network of companies that are brought together by the producer so the producer is involved over the entire time of the value provision, but the customer is supported by a network of companies

PROTEUS Workbook #6 by Andersen et al. (2013) presents early ideas and frameworks to handle partnerships considerations in PSS for industry practitioners (Andersen et al. 2013). Among other frameworks it presents a matrix where different interaction types are presented in connection to the different network described by (Möller and Rajala 2007); current, renewal and emerging.

The EU project HiCS (Highly Customerized Solutions) had its focus on Solution Oriented Partnerships (SOP), within which a framework was developed – the SOP Methodological Framework – with focus on partner-based solutions and a co-production of sustainable solutions (Manzini et al. 2004). Most of the cases used were focused on consumer products and there were not many B2B cases investigated. This methodological framework guided the HiCS project's research and development of methods and tools. With a philosophy that a continuous coordination between progress (in development of the PSS solution) and relationship development should be made. Within this project they observed indications of the SOP:

- Can be both pre-planned or can emerge from interaction.
- Might need a need focal orchestrator, to conduct the co-ordination.
- A key ability was seen to be able to describe PSS concept on an abstract form, to recruit new partners.
- Is feasible to coordinate simultaneously with the PSS solution.
- Brings new benefits and new solutions those companies that embrace these new forms of partnerships.
- The SOP can emerge in parallel with delivery of a solution.

In line with the focus on relationship as an asset to the company, Wallin (2011) focuses on how a company increases its PSS innovation capability through collaborative networks. She presents a model called 'Networked Competence Innovation Model' and argues that a 'designerly approach', with the three elements: operational; strategic; and tactical, would be important dimensions when assessing the competencies within a company to handle short-term and long-term perspectives of collaboration. The focus of the model follows an argument that visualisation and prototyping is needed if collaboration should be nurtured in all of its different phases. One of the models for visualising the 'collaboration competence development possibilities' is presented as a table, containing a set of seven collaboration types, categorised based on which stakeholders can collaborate internally and externally (Wallin et al. 2011).

Within the PSS literature, many 'transition frameworks' have been presented and many of these focus on the journey from a product-oriented business to a more service-oriented business. This was done by: i) describing the change a manufacturer needs to undergo; or ii) presenting different strategies for changes. Within such transitioning frameworks for PSS strategy development, the ecosystem of the PSS appears frequently:

- Customer-supplier interface changes when going from product focus to customer focus (Martinez et al. 2010).
- Organisational Intensity vs. service specificity (Mathieu 2001b).
- The Install Base Service Space through Relationship-based services (Oliva and Kallenberg 2003).
- A Value Stream Approach, going upstream or downstream (Davies 2004).
- Business process integration, different strategies for supporting offering solutions (Matthyssens and Vandenbempt 2008).
- Descriptions of how the organisation should organise in terms of front and back end units strategically (Foote et al. (2001).

Despite these frameworks, limitations were found in detailing and describing changes in the ecosystem or integrating the network into conceptualising new PSS solutions.

2.3.2 Network factors and influencers

When describing an ecosystem constellation or possibility for a changed collaboration or partnership with external parties, it is important to have insight on what contributes to successful collaboration (Cousins 2002; Mason et al. 2006). If we take a look at the essential dimensions of an organisation related to PSS strategy described by Tan et al. (2009), service-oriented strategies for manufacturing firms is argued to consists of six main dimensions Figure 6. It is argued that these can be viewed in hard and soft organisational dimensions, where culture and people & competencies are soft dimensions. These cannot be 'designed' but are essential dimensions of a strategy. These can be closely compared to many of the success factors for collaboration, as many of these are related to social behaviour (e.g. trust, commitment and communication) and are also called people-related factors (Tidd et al. 1997).

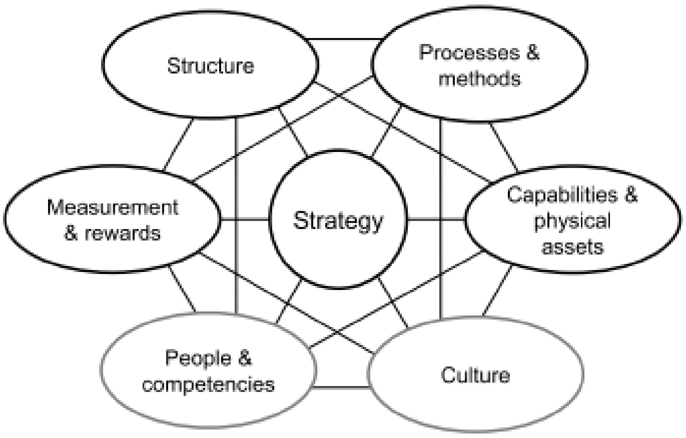


Figure 6: The essential dimensions of an organisation related to strategy (Tan et al. 2009) based on Galbraith (2002) star-model.

Factors that influence partnership success can be as follows:

- Trust, commitment, information sharing, joint problem solving, and coordination (Mohr and Spekman 1994) .
- Trust, flexibility, senior management support, sharing information, joint problem solving, continuous improvement, and involvement of relevant personnel (Humphrey and Schmitz 2002)[1].

Within 'collaborative product development' also these success factors, or influencers on the outcome, are in focus, as studied by Bruce et al. (1995), presenting top factors grouped as: rules; people; process equality; and choice of partner. Besides these factors, focus has also been on common failures and the effect of collaborative product development processes (Tidd et al. 1997). Within this research project, the *hard* dimensions have been in focus and little attention has been on the social aspects of the relationships.

Developing PSS and focusing on *solution development*, Windahl and Lakemond (2006) present six important factors influencing the development of integrated solutions, by this is understood what influences and hereby can explain the success or failure of an integrated solutions.

Factors	Description
Strength of the relationship	between the different actors involved in the development project
Firms positions in the network	e.g. being integrator or supplier to an integrator

1 A Master's thesis project, with the title; *Understanding Customer Relationships in a Product/Service-System*, connected to the comparative case study of this research project, had a literature review on partnership success factors, where a set of 20 identified factors were found and selected across 15 authors.

Firms network horizon	view on the network, e.g. broadening the network perspective, to include customers customer
The solutions impact on existing internal activities	Such as product, service and production structures
Solution impact	The (developed) solutions impact on the customers core processes
External determinants (also process focus)	The (developed) solutions impact on the external determinants and their core processes

Table 4: Six important factors influencing the development of integrated solution – adapted from (Windahl and Lakemond 2006)

Of all six factors, only the fourth does not have a direct relation to the inter-organisational relationships within the ecosystem dimension of PSS. As Windahl and Lakemond (2006) elaborate, they broadened the complexities of developing PSS designs by showing that the inter-organisational relations may be just as important as the intra-organisational relations, in contrast to the focus on the customer centric organisation by Galbraith (2002) and the internal capabilities by Davies et al. (2006). Particularly, the 'supply chain position' the micro-vertical integration practices has been investigated in connection to offer PSS solutions by (Wise and Baumgartner 1999; Baines et al. 2011), where Baines et al. (2011) illustrate the importance of not just the firms position in the network, but all of the six factors listed by Windahl and Lakemond (2006), as *"… these demand that a manufacturer is responsive and often to achieve this, they may have to vertically integrate if they are to avoid either excessive costs for stock holding or incur penalties for failing to deliver against a services contract …"* (Baines et al. 2011, 953) p. 953. Wise and Baumgartner (1999) present a list of metrics from which to evaluate quantitatively whether a servitisation of the company was suitable based on a set of nine categories divided into three main categories: i) Attractiveness of going downstream; ii) Importance of Customer Relationships; and iii) Power of Distribution Channel[2]. Furthermore, they list four sets of Successful Downstream Business Models, which they call 'The Spectrum of Downstream Moves'. None of the metrics or downstream moves integrates the perspectives of cultural or organisational nature, as, for example, is the case with the six factors mentioned by Windahl and Lakemond (2006). These different factors mentioned above, point towards a necessity to view the 'strategy' with all six dimensions mentioned by Tan et al. (2009) carefully and make the strategy decisions based on a network of stakeholders, not from a single 'leading/host' company.

[2] Measures were listed as e.g.; Ratio of install base, Market share, Distribution expenses and Magnitude of Product-based differentiation.

2.3.3 Network representations

Guiding this subsection was the following activity: Investigate what kinds of representations are currently used to support the synthesis of the PSS ecosystem to allow PSS conceptualisation.

As stated previously, ecosystem modelling approaches within PSS have not been a specific focus for the research field. Lim et al. (2012) focus on tools to visualise PSS, where all the contributions are divided into two categories, one of which is exactly the ecosystem dimensions of a PSS, namely 'Relational network of stakeholders'. The focus is only within the field of PSS and the contributions to ecosystem visualisation are therefore sparse, covering only four different modelling approaches. Furthermore, Krucken and Meroni (2006) focus particularly on the need for communication tools and describe these on three levels. See Figure 7 from: i) core group of developers; to ii) operation and delivery; and finally iii) the end-users. A particular focus here is on the complexity of information that needs to be shared when building new ecosystem structures, as partnership-based solutions are increasing in society (Krucken and Meroni 2006). Within the research project HiCS a core focus is placed on establishing methodologies to facilitate a process of developing *Partner-based solutions (*also described in 0) Solution Oriented Partnerships are not detailed by structure, goal, or stakeholders but by the importance of the stakeholders collaborating through a common vision, which is suggested to find place through 'strategic dialogue', guided by Communicating Social Medias (CSM) (Krucken and Meroni 2006).

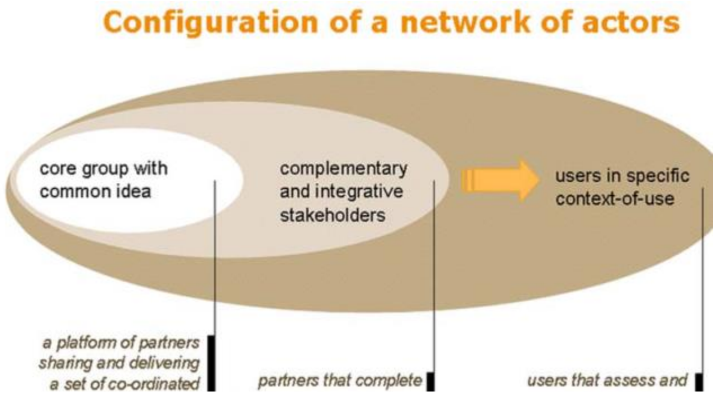


Figure 7: Communication tools for collaboration adapted from (Krucken and Meroni 2006)

Network modelling and analysis has existed for a long time, and within an industry context the supply chain analysis (later Supply Chain Management) was supported by conceptual models, such as Michael E. Porter and the supply chain approach. Later, with the focus on breaking down the value chain, to replace it with a new understanding of market mechanism, e.g. value nets (Bovet and Martha 2000), and value systems (Normann 2001), co-creation with the customer (Prahalad and Ramaswamy 2004), reaching all the way from structuring business strategies, to the way products were developed, created and consumed. Network analysis became a new topic, and the supply chain was replaced with a network of stakeholder in a complex net, requiring different methods for analysis. Camarinha-Matos and Afsarmanesh (2007) listed a set of theory areas Figure 8 of which inspiration could be leveraged into Collaborative Networked Organisation (CNO), with areas such as multi-agent system, Network analysis, Social network analysis, self-organising systems, and game theory[3] which is a direct list of inspiration for PSS ecosystem modelling as the PSS can be viewed as a CNO. The amount of network modelling approaches call for a framework and in-depth analysis of when to use which models in connection to context, application area, and level of depth (Camarinha-Matos and Afsarmanesh 2007). This applies to the network approaches used in the PSS field as well. Many of the modelling approaches within PSS research are used to describe the need for a network approach and to stress that many stakeholders are an integrated part of the PSS solution. Only a few of the methods are used in the context of a real case with practitioners as is the case with (McAloone and Bey 2009; Matzen 2009; Tan 2010; Morelli 2006). Many of the approaches use a case and/or a scenario for presenting the technique but not all include a procedure or 'how-to' description to apply in the mapping activity.

3 See also Appendix F: Theory areas and their potential applicability to CNO, for a list of all the theory areas detailed.

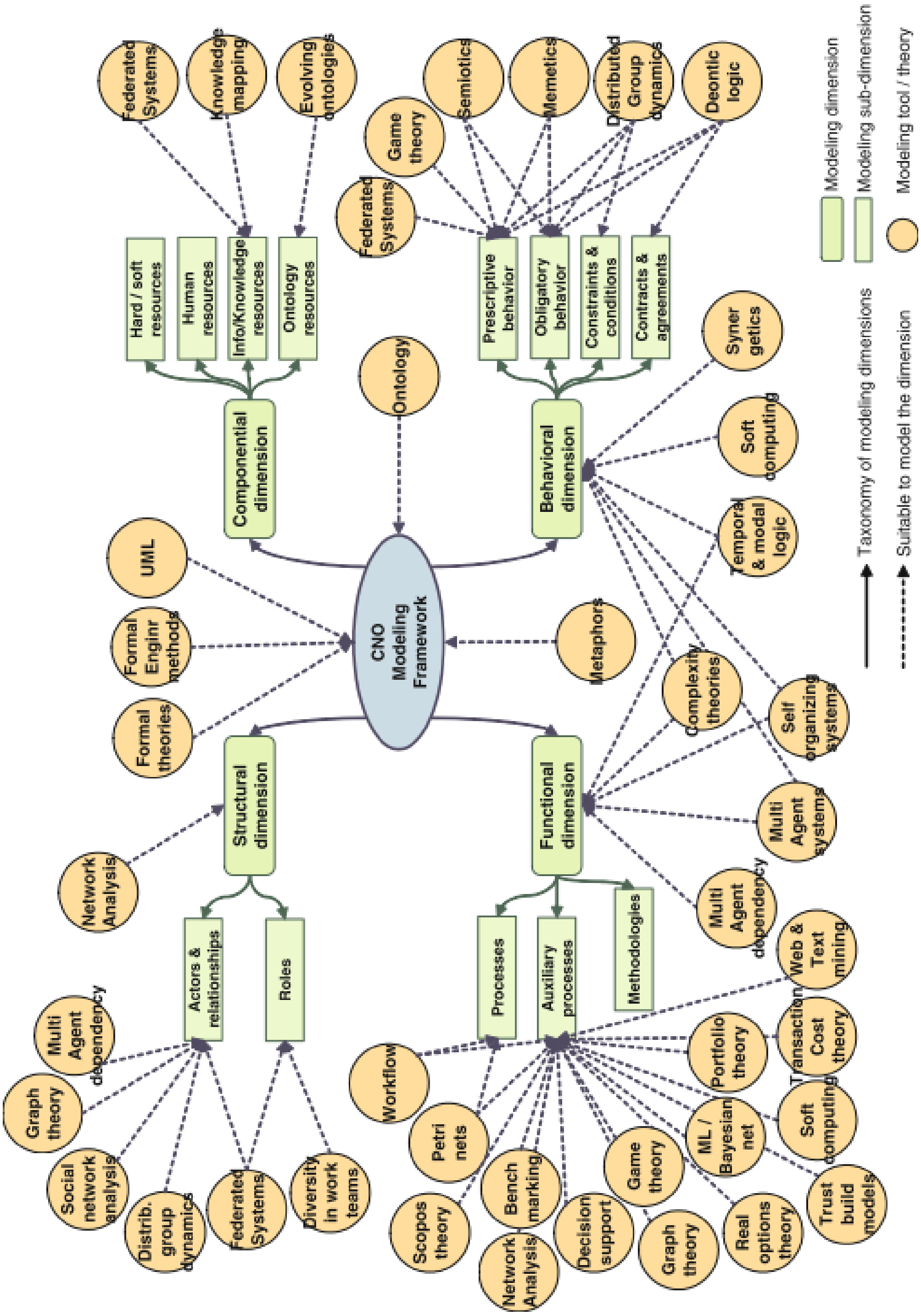


Figure 8: NVA - overview of network approaches adapted from (Camarinha-Matos and Afsarmanesh 2007)

Figure 8 summarises the most dominant approaches to ecosystem modelling in the literature. As the topic is emerging, the table displays not just journal-based results but also contributions from PhD theses, peer-reviewed conferences, and PSS-related research topics.

Table 5: Overview of dominant ecosystem modelling in literature. Modelling techniques and tools for usage in PSS development

Name	Focus and usage area for tool or technique	Author and year
Modelling framework for "Collaborative networked organisations [CNO´s]"	Using a set of four dimensions; Structural, componential, function, behavioural.	(Camarinha-Matos and Afsarmanesh 2007)
Conceptual model of service-value networks. "Services ecosystems as value networks"	Includes both products and services. Described as complex socioeconomic systems, analysed using simple node and arc, to model structure and dynamics, by using main stakeholder group.	(Basole and Rouse 2008)
Customer Value Chain Analysis methodology (CVCA).	Value flow mapping focus on active stakeholders, guided by a seven step procedure. The goal of this is to prepare product development decisions.	(Donaldson et al. 2006).
Map of interaction	Main stakeholder groups, and main interaction between and participation of all stakeholders. Focus is on "narrative" tools in the conceptual phase. Indirectly and indirectly stakeholders.	(Morelli 2006)
System Organisation Map	Delivery network representation, flow of material and information.	(Manzini et al. 2004)
Solution Map	(Same as above) Delivery network representation, flow of material and information.	(Evans et al. 2007)
System map	Active relations of key stakeholders. Allowing in-depth interpretation and an overview of the system.	Van Halen
Evolutionary Stakeholder system map (ESSM)	That is the potential stakeholder network, and its evolution in time, needed to carry out the transition path.	(Vezzoli 2007; Vezzoli et al. 2008)
Service ecology map	A visualisation of a system of actors that form a service and the relationship between them. A service ecology map represents a systemic view of a service and the context it will operate in.	(Moritz 2005)
Value network analysis (VNA)	In the context of organisational development, in all scales, inter and intra-organisational relations. Mapping; nodes,	(Allee 2000)

	links and deliverables. Tangibles, intangible (including value, as e.g. co-branding, or customer loyalty)	
Value flow mapping – a stakeholder derived requirement analysis.	Modelling technique and process description. Analyse how value is created and transmitted. Nodes (main stakeholder groups) and value: Policy, Money, workforce, Technology, knowledge and goods and service. Focus on value loops, and lengths.	(Cameron et al. 2008)
Visualisation of a use case "scenario"	Activity flow mapping, by analysing goal and dependencies of the actors. Mapping; Product, process, process owner, service component.	(Mittermeyer et al. 2011)
Network Value Analysis (NVA)	Provides a process of the analysis covering five steps. Mapping partial Value Map. Mapping; Exchange goods and services, Affection and linking (emotional), information and ideas (cognitive), influence and power (prescriptive).	(Peppard and Rylander 2006)
Stakeholder-network	Step-by-step approach, by mapping, stakeholders and links as; material and information. With a mapping of also significant environmental impacts of identified relations.	McAloone (Environmental Guide) stakeholder mapping
Activity Modelling Cycle	Activity Modelling Cycle (AMC), using the approach of Vandermerwe (1999), (Vandermerwe 2000)with a customer activity cycle, where for each activity the network of stakeholder is mapped.	(Matzen and McAloone 2006)
Service Engineering i) view model ii) Scope model iii) flow model iv) scenario model	Using different design object domains, represented in each of the four models. Scope and flow describe the actors related to the service, and in this way support insight into behavioural dimension.	(Sakao and Shimomura 2006)
Supply chain	Simplistic view of a supply chain. Mapping value chain link, business relation and innovation relation.	(Wallin 2011)
Organic visualisation paradigm applied by the tool Organic Viz.	'The organic visualisation paradigm' applied with use of the tool 'OrganicViz' for analysis of engineering system design.	(Storga et al. 2013)

Table 5 illustrates that different approaches exist and are used already within PSS development. They are distinct from each other within a few parameters, e.g. the type and details of the nodes varies. This can be described as the *level of resolution* (Allee 2000) or *model intent perspective* (Camarinha-Matos and Afsarmanesh 2007) and is the scoping and level of nodes included. Furthermore, the choice of what is modelled (the node type), e.g. activity based nodes or a stakeholder node (single or groups of stakeholders/activities), distinguishes the different approaches. This is described by Camarinha-Matos and Afsarmanesh (2007) as different dimensions of a network modelling, i.e. structural, functional, behavioural, and componential dimensions. Where, for example, service engineering takes the activity focus (functional dimension), through for example graph theory or work flow (described by Matzen (2009) as a 'data node actor network modelling approach') an example of this, is the approach 'scope and flow view' by Sakao and Shimomura (2006). The same is observed in the service design field, with e.g. service blueprinting described by Shostack (1982), here a set of activities are mapped in parallel sequences covering and detailing user and front and back-office staff activities.

Social Network Analysis (SNA), also referred to as Organisational Network Analysis (ONA), has been used, see for example (Basole and Rouse 2008), focusing on a structural analysis of network linkages, where only one linkage exists between stakeholders, which presents opportunities for analysis of structural holes, degrees of separations between entities, betweenness etc. Though SNA does not directly address economic or social value creation (Allee 2000). *Its use [i.e. SNA] as a managerial tool is limited because of the high level of technical expertise required to analyse and interpret the network patterns (Allee 2000).* The Value Network Analysis (VNA) presented by Allee and the Customer Value Chain Analysis (CVCA) methodology both focus on financial and non-financial asset utilisation. This type of analysis focuses specifically on improving organisational performance by understanding the actual value creation and its dynamics. The VNA focuses on three mapping elements: (1) the nodes; (2) a transaction; and (3) deliverables, and defines the network as: "*... a set of roles and interactions that generates a specific business, economic, or social good.*" The methodology in comparison to the CVCA also includes intangibles besides information—exchange of value where the benefit could be: customer loyalty; image enhancement; co-branding opportunities; etc. Two items of interest in the VNA methodology are 'collaborative work design' and 'value creating networks' and therefore suitable to support the aim of PSS as it is designed for the purpose of strengthening collaborative behaviour in the network and looks at multiple relationships in the network, not just at the customer (Mougaard et al. 2012).

Many of the modelling techniques within the PSS field, occur within this category of VNA, e.g. Stakeholder network (Morelli 2006); Stakeholder System Map (Vezzoli 2007); System Organisation Map (Manzini et al. 2004); Stakeholder-Network Map (McAloone); Stakeholder Network (Tan 2010); and Partial Actor Network (Matzen 2009). It is believed that network modelling reveals a vital part of the business model of the company (Donaldson et al. 2006; Tukker and Tischner 2006a) and can directly support the value understanding of each stakeholder, identifying new or improved value propositions for the customer.

Furthermore, differences in the modelling approaches are found in the choice of taking into account 'active' and 'non-active' stakeholders, also called direct and indirect stakeholders, connected to the business/system. The approach by Bijker (1997) *Relevant Social Groups*, includes direct and indirect influencers, as not only those groups that are actively taking part of e.g. the development of the PSS is included, but also those that indirectly participate, together with those stakeholders that may counterwork the development. This approach is necessary to include in PSS, described by Morelli (2006) as:

"Such a perspective helps defining a complex picture of the scenario in which the PSS is supposed to be developed" Morelli (2006).

Also described by Matzen (2009) as the importance of knowing all stakeholders (influencers) in connection to a product life phase:

"*... in order to identify possible beneficial service activities throughout the product life, it is important to know the constellation of all possible stakeholders in the relevant product life and particular activities*" (Matzen 2009) p. 81).

Tan (2010) reflected that the CVCA could also be expanded to include stakeholders not currently taking part in the system, as to support the establishment and maintenance of new relations for the PSS. This approach are broadly seen in the service design field literature, and named 'service ecology' (Moritz 2005), as is seen in the examples of *Map of Interaction* and *Stakeholder System Map*. Including stakeholders outside the current value chain in development and evaluation of PSS concept is vital. Mont (2004) presented an approach, listing both 'current active', and possible 'future active' stakeholders to include in evaluation of a PSS solution, where obstacles and benefits were listed for all stakeholders in a set of scenarios.

In Service Engineering, multiple models are said to be needed, as presented by Sakao and Shimomura (2006): i) view-model; ii) scope-model; iii) flow-model; and iv) a scenario-model. These four models can be compared to step-by-step processes, where overlap is present in the different layers of modelling, suggested by Donaldson et al. (2006), Cameron et al. (2008) and (Allee 2000). The process suggested by Allee (2000) named Value Network Analysis has four main steps as shown in Table 6.

Table 6: Value network analysis - four main steps adapted from (Allee 2000)

Main step	Description of the step
Scope & boundaries	Deciding a goal of the mapping, as well as the boundaries; what should be mapped.
Stakeholders/nodes	Identify the participants of the network, what type of nodes should be mapped. Level of detail: The resolution of the network. Contributing role within that activity.
Mapping transaction	Hereafter the transactions are mapped, which are a directional arrow, symbolising that something are moving from one to another. The attribute of the link between the stakeholders are hereafter mapped, which are the deliverables
Sequencing	The last step is sequencing which implies that each activity is in an order in the network, in this way it´s possible to validate the network.

It is observed that the interplay between the different models and process steps within the frameworks, gives the insight needed. This is described within the VNA approach as “arising between the different process steps”, and has been observed by both Matzen (2009) and Tan (2010) in their case studies where a network modelling approach was tested, and different models were used in iteration, and therefore presented as an important part of their final PSS conceptualisation framework.

2.4 PSS and inter-organisational urgency

PSS conceptualisation frameworks, and PSS strategy models exists, as just presented above, but these have limited or no guidance in how to conceptualise different ecosystem solutions. This section will cover other fields of research on network assessment, to transfer models, and approaches here from, to achieve new knowledge for the development of a suitable tool to aid and strengthen conceptualisation of PSS with point of departure in the ecosystem perspectives of a PSS.

2.4.1 Consolidation towards a multiple stakeholder approach

There is a consolidation within literature towards the opinion that multiple stakeholders ought to be viewed from a network perspective and not as the classical value chain process, presented by Porter and Millar (1985) where the market is separated from the value creation process (McAloone et al. 2010b). An intense focus from many scholars is rooted in the belief that the value creating process should be viewed as a dynamic network, as opposed to a sequential chain. Normann (2001) presents the *Value Star* as the mental model of how to view the total value creation system of a modern business innovation process, within which all stakeholders should be seen as *organisers of value creation*. A similar belief that the value chain should be replaced with a value system is found through Prahalad´s notion of the experience network, which is based on a non-linear and non-sequential process of stakeholders, creating an environment within which individual customers are supported by a network of companies and different communities to co-create value together (Prahalad and Ramaswamy 2003). Bovet and Martha (2000), use the term *Value nets* as a new approach to gain a competitive advantage and break away from the somewhat dusty sequential supply chain concept.

Within business literature, a new view on market competition has been described by scholars, which is that competition should be seen as "value chain against value chain". With global markets, competition does not take place between individual businesses but between value chains (Horvath 2001). Or in the network perspective "System against system": "*... it is not the competition between single companies that defines today's market—but value system against value system that leads the business landscape*" (Sahay 2003). The single producer has no chance competing against collaborative value systems. It is claimed that the most competitive value system is the one where the shared value is the highest (Ring and Van de Ven 1994). Supply Chain Management has brought many tools and benefits for supply chain functions, such as: inventory control; order fulfilment; and purchasing – but supply chain management is argued to be too narrow a concept, as efficiencies and innovation possibilities lie also across large business processes and between entire supply chains (Sahay 2003). An in-depth study carried out by Payne and Holt (2001), of past and current literature in connection to value, describes the recognition of *relationship value* as the most recent development and points towards the customer-supplier relationship as being expanded within the new paradigm of *relationship marketing*. The field of relationship marketing emerged from service marketing (Grönroos 1994) with a new aim of replacing that of marketing with the transfer of ownership;

"*... To establish, maintain, and enhance relationships with customers and other partners, at a profit, so that the objectives of the parties involved are met. This is achieved by a mutual exchange and fulfilment of promises ...*" *(Grönroos 1994)*.

The ecosystem changes from customer relationship management to network management, with a portfolio of all relationships, where the management of the network requires management of all synergies and co-ordination of all relationships (Möller and Rajala 2007; Arlbjørn et al. 2011; Payne and Holt 2001). Normann (2001) more loosely defines this by reconfiguring the business landscape. Which brings with it a challenge, as there are no holistic views to management mechanisms for approaching and managing these many new relations in a system view (Möller and Rajala 2007). Literature on network management mostly focuses on single networks and how these can be used to strengthen a company's development organisation, describing only to a small extent how to sustain and re-develop a relationship to enhance the utility of a system.

The network view is different from the traditional buyer-supplier constellation, as inter-organisational networks can cover networks outside the traditional supply/value chain, as *technological innovation* and *product development networks* (Möller and Rajala 2007) and co-operative networks (Cravens et al. 1993), where competing firms join forces to strengthen their competitiveness. A fundamental shift has been underway since the turn of the 21st century, where the dyadic (two-way) view of inter-organisational relationships is changing to a network perspective, where value creation occurs between different types of networks involving many different relationships (Achrol 1997; Basole and Rouse 2008). Here, a network can be understood as a set of connected relationships between firms (Hakansson & Johanson 1993) and the single relationship is being replaced with a network of relationships. The supplier/customer-relationship is therefore not the only relation to be changed; a plethora of different relations need also to be defined and detailed.

2.4.2 Innovation frameworks – innovation by new relations

Within innovation literature, many frameworks explicitly claim the importance of the network. One of these frameworks by Tidd et al. (1997) categorises innovation in four different types: Product Innovation; Process Innovation; Position Innovation; and Paradigm Innovation. New value propositions within PSS can be seen as Paradigm Innovation, and Product and Process Innovation can be seen as closely linked, as all products should be developed based on the processes connected—the service activities. Position innovation entails the reorganisation of the stakeholder network - “the ecosystem”. Tan (2010, 156) argues that PSS brings with it an expansion of the degrees of freedom in design and therefore a need for these different perspectives to be activated in the conceptualisation of PSS. Windahl (2007b) uses the same framework to compare PSS to all four innovation types. Furthermore she uses Henderson and Clark’s (1990) innovation framework, where innovation is classified based on the linkages between components and the state of the components. Four different types of innovations are presented: i) Incremental; ii) Radical; iii) Architectural; and iv) Modular innovation. These four types of innovation can support the identification of change needed within the organisation (Windahl 2007b). Architectural innovation is argued to be of high importance, when dealing with high-cost, complex engineering products (Windahl 2007b; Davies et al. 2006) and directly connected to the organisation’s structure and body of knowledge, as these products/systems consist of multiple sub-systems and many components, potentially sourced from a myriad of suppliers and sub-suppliers. This is why small changes in interface between systems or components might require a high degree of co-ordination, as many stakeholders might be affected by this change.

2.4.3 On network elements and classifications in extant literature

In product development, expansion of the development task to include different people is not a new phenomenon; e.g. 'integrated product development' was presented in (Andreasen and Hein 2000) and described how different organisational aspects should be aligned within the development process to reach efficient and effective product and technology development. User-centred design focuses on the needs of the end-user, which are integrated throughout each of the design stages, and user-driven design (participatory design and cooperative design) where the user takes part in the design activity. Also dubbed co-design with users by Prahalad and Ramaswamy (2004), user involvement is classified by Kaulio (1998) in i) designing for; ii) designing with; and iii) designed by. Furthermore broadly leveraging on and exploiting external network resources through open design, by crowd sourcing (Aitamurto and Tee 2011; Howard et al. 2012) or open innovation (Chesbrough 2003) are approaches used by many companies to gain new competencies, new knowledge or expand resources, where the design *for, with* and *by* users are getting blurred. Designing for a new market, taking into account social behaviour, culture, and industry trends has been the objective of many innovation theories designing for a new market, or *designing the new market*, as e.g. the red and blue ocean strategies (Kim and Mauborgne 2005). Normann (2001) uses a similar metaphor namely the density of the business landscape. By this approach, exploration of new configuration possibilities can lead to a prime mover position – first to market.

Network elements

Gulati and Kletter (2005) presented the relationship as a capital asset to companies, and coined the concept of a '*relationship-centric organisation*' by a framework that combines four different company strategies and four critical stakeholder groups. They observed a trend in top performing companies on the Fortune 1000 list that they termed '*shrinking their core'*, which reflected the fact that companies increased focus on fewer activities and outsourced the remaining through new network relations. The framework acts as a conceptual understanding of how companies move towards 'collaborative relationships' when moving from selling commodities to selling solutions. The metaphor of the latter is used to describe the different relationship levels, where moving upwards intensifies the collaborative effort within the relationship. The top levels in all four categories were described as: *"Suppliers are strategic partners, internal sub-units are mutually aligned collaborators, alliance partners are part of a mutually reinforcing set of business relationships, and satisfied customers are collaborating on co-developing and receiving solutions ..."*

(Gulati and Kletter 2005, 80). This framework does not focus on how to analyse the ecosystem, but on what changes in the relationship (the intensity). A step-by-step approach is presented to enhance the relationship.

Other frameworks describe process elements of the inter-organisational relationships (Ring and Van de Ven 1994; Lambert and Knemeyer 2004), as to be capable of designing and executing a network development, both decoupled from product development.

The Partnership Model presented by Lambert and Knemeyer (2004) is a model of how to support partnership building to achieve what they called ‘effective partnerships’ in the context of Global Supply Chains (also referred to as value systems) with a focus on suppliers. The model presented four main dimensions: i) drivers; ii) components (i.e. joint activities and processes); iii) outcomes; and iv) facilitators. To support the model, a scheme for ‘Management Components for Partnerships’ is presented, which consists of four partnership components: planning; joint operating controls; communication; and risk/reward sharing, plus variants of these on a low, medium, and high scale. These models are designed to be used in a one-day workshop with a potential supplier already selected for a review. Within this framework, contrary to the relationship-centric organisation framework by Gulati and Kletter (2005), a single stakeholder view is presented, compared to a set of vital stakeholder groups, though the models seems to be generic.

Looking in-depth into a classic product-supplier relationship creation within the car industry, a partnership model is presented by Jeffrey and Thomas (2004), combining models of Honda and Toyota, resulting in a hierarchy model, where six distinct steps are described. None of the steps may be skipped but should be viewed as a system to approach supplier relationships. This model emphasises the need to know how the suppliers actually work, with this being the first step before moving up the hierarchy to finalise with conducting joint improvement activities. Within this model, the superior level was similar to the highest collaboration opportunity of Gulati and Kletter (2005), with ‘strategic partnering with suppliers’ or ‘integrated business with alliances partners’.

Another process framework presented by Ring and Van de Ven (1994) introduced a conceptual framework through which cooperative inter-organisational relationships (IOR’s) can be assessed to understand how they emerge, grow and dissolve over time. They saw IOR’s from a developmental process perspective as: *“... socially contrived mechanisms for collective actions, which are continually shaped and restructured by actions and symbolic interpretations of the parties involved ...”.* They base their framework on Commons (1950) original conceptualisation of transaction and named the stages: Negotiations; Commitments;

Executions; and Assessments. The cooperative IOR is a repetitive sequence of these stages in a cyclical manner. Within this process framework, a focus is on formal and informal activities of the individual stakeholders to be continued throughout the relationship to maintain it, whereas the model by (Lambert and Knemeyer 2004) is merely developed to support a point in time selection, not how to maintain the relationship when implemented.

Many frameworks dealing with relationship/network management have also been presented (Payne and Frow 2005; Möller and Halinen 1999). It is interesting to notice here the difference in focus on: i) development; or ii) management of relationships. Customer Relationship Management (CRM) is an example and also another example of a *single* stakeholder view within the network. Payne and Holt (2001) revisit the large amount of literature concerning CRM to bring clarity, with the aim to develop a conceptual framework for CRM strategies and with a focus on how customer value adds to total shareholder value. Later, Payne and Frow (2005) present a framework for *'Relationship value management'*, building on the marketing paradigm with the belief that multiple stakeholder views, not a single stakeholder, should be taken. The framework includes different key stakeholders, called 'customer markets'. Compared to Gulati and Kletter (2005) view on four key stakeholder, this Relationship Value Management framework uses the 'six market models' by Peck et al. (1999) grouping stakeholders into six categories. The framework presents a central value process in the middle (value determination, value creation, value delivery, and value assessment) surrounded by the stakeholder interaction processes, with the six markets divided between three main processes: i) customer; ii) employees; iii) external stakeholders.

Networks have been viewed as self-organising systems (Håkansson and Ford 2002; Håkansson and Snehota 1995), whereas the strategic management perspectives suggests that also strategic networks created intentionally exist (Nalebuff and Brandenburger 1997; Möller and Svahn 2003). The co-existence of both approaches is suggested by Möller and Rajala (2007) to be the right approach for companies to navigate the ecosystem. They suggest a framework with a classification of networks using three elements: i) an ontology; ii) management mechanisms; and iii) classification of network types. They present three categories, based on an innovation approach for current business: (No change); renewal business (incremental change); and emergent business (radical change). For each of these categories, they divide seven identified networks from theory. There is no particular guidance in how to use the framework, and furthermore the framework is only validated through a theoretical perspective. They describe the development of a relationship as an activity between two parties, requiring alignment and when established it exists by the relational activities between these two parties:

"... The development of a relationship (of activity links, resource ties and actor bonds) between two companies cannot be unilateral; it requires co-alignment of two parties. How it will develop depends on how each of the parties act and react in the relationship. Once established, a relationship has a life of its own, it gets its own substance as a dyad. It is improved or deteriorates as a result of actions taken by the parties ..." (Snehota and Håkansson 1995, 42)

Network classifications

Much of the literature on the topic 'management of networks' points towards the necessity of being able to categorise the different network configurations, to be able to match different management strategies or mechanism for each (Möller and Rajala 2007).

Two-by-two matrices supporting decision making: The categorisation of networks is described through matrices. These have been presented to compare alternative strategies to partnership configuration. Besides management and development frameworks, there are so-called 'support models' (e.g. deciding upon the right relationship). These matrix models have been developed to aid the company in partnership decisions by listing network dimensions, parameters, characteristics influencing each other, and thereby pointing towards different strategies. Cravens et al. (1993) present a matrix called "*Hybrid Interorganisational arrangements*", presenting four constellations matching environmental diversity (culture, etc.) against resource gaps, each measured in high and low, resulting in four types of co-operative inter-organisational relationships: 1) Acquisition/merger; 2) strategic alliance; 3) in-house strategy; and 4) joint venture. This framework does not focus on vertical relationships but aims to distinguish between strategic alliances and joint ventures, where the goal is merely the same cooperating with an external stakeholder, with either building a new 'unit' through venture or a strategic alliance if the culture and environment within the two organisations' 'soft organisational capabilities' were too diverse.

Another matrix-like model by Camarinha-Matos and Afsarmanesh (2006) focused on 'collaborative networks', despite this being horizontal or vertical, by presenting different network types, what was termed 'coalition types', illustrating that the integration level increases when the 'collaboration' advances. Where building blocks of integration are added for each move towards higher collaboration, four different levels are presented: i) Networking; ii) Coordinated; iii) Cooperative; and iv) Collaborative Networks. These definitions were used to give a context for 'collaborative networks', which they later presented a taxonomy for. Below is their working description for Collaborative Network (CN), and this definition corresponds perfectly to the aim of PSS and the need for enhanced focus on collaborative behaviour within the ecosystem perspectives:

"... [CN] is a network consisting of a variety of entities (e.g. organisations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by computer network ..." (Camarinha-Matos and Afsarmanesh (2006) p. 30)

Excessive lists of network constellations: Presenting a set of main network types has been suggested by a set of authors: (Achrol 1997; Möller and Rajala 2007; Camarinha-Matos and Afsarmanesh 2006; Powell and Grodal 2006; Tidd et al. 1997), though there is a lack of consistency and agreement of which categorisations to make. These different descriptions are not provided to analyse the network constellation but merely to distinguish between different networks, e.g. providing a terminology to describe a relationship and an overview of what kind of constellation can be found and created. Powell and Grodal (2006) mentioned a set of characteristics from which different networks could be distinguished.

"... One can differentiate networks with respect to their duration and stability, as well as whether they are forged to accomplish a specific task or evolve out of pre-existing bonds of association. Networks vary from short-term projects to long-term relationships, and the different temporal dimensions have important implications for governance. Some networks are hierarchical, monitored by a central authority; while others are more hierarchical, with distributed authority and strong self-organising feature ..." (Powell and Grodal 2006, 60)

Powell and Grodal (2006) presented a list of four key types of innovation networks, which were to be seen as overlapping and not essentialist categories, as presented in .

Table 7: Four key types of innovation networks – based on (Powell and Grodal 2006)

Type of network	Description
Informal networks	Based on shared networks
Project networks	Short-term combinations to accomplish specific task
Regional networks	Where spatial propinquity helps sustain a common community
Business networks parties	Purposive, strategic alliance between two

This list of key innovation networks clearly illustrates how different characteristics are used to create the categorisation. Furthermore, they developed a network typology based on a matrix with informal/contractual vs. highly fluid and more closed membership. Each of these four categories of networks was described by: nodes, function, structure, and an example. Möller and Rajala (2007) presented seven network types by three main categories refer to Table 7. The main focus for this list was to analyse the different managerial mechanisms for each.

Table 8: Seven network types – adapted from model by (Möller and Rajala 2007)

Current business nets	Renewal nets	Emerging business nets
Vertical demand /supply nets Horizontal markets	Business Renewal nets Customer solution nets Application nets	Dominant design nets Innovation networks

To better understand the role, behaviour, and impact of different network types, specifically 'collaborative networks' as mentioned earlier by Camarinha-Matos and Afsarmanesh (2006), they also presented an extensive list of network types with a focus on different 'organisational forms'. The main differentiator of these networks was based on whether the network was goal-oriented with intense collaboration (towards a common goal) or long-term strategic alliances through cooperation. It was argued that the governance and value creation was different in each constellation and "*… Therefore, a variety of organisational forms, including a mix of long-term strategic alliances and very dynamic short-term coalitions, shall coexist …" (p. 27)*. Furthermore, as the network is described by being geographically disputed and perhaps not having a host organisation, the term 'virtual' is used to emphasise this. Eleven different constellations are listed with examples like: virtual enterprise; virtual team; industry cluster, etc. In general for these different networks constellations implies that they are very specific like e.g. 'Disaster rescue networks'.

Focusing on value chain integration, Mason et al. (2006) present an integration typology with the aim to support a demand-driven supply chain configuration, where companies need to match and adapt the business to market demands, which is vital in a PSS context to manage agility in the whole value chain to match user-need long-term. Mason et al. (2006) use a continuum for the typology representing a supply chain with a set of seven different integration possibilities (e.g. from transactional to relational and strategic alliance to full vertical integration). Despite the focus on the different integration possibilities, the findings point towards 'quasi-integration', where not a single but multiple of the integration types are combined.

Value logic within the network: To distinguish and describe different network constellations, the value logic is also used (Möller and Rajala 2007; Gulati and Kletter 2005; Stabel and Fjeldstad 1998). An example is the notion about a network constellation being a 'network of organisations'. This can cover any constellation as the market always can be described as a macro network (Snehota and Håkansson 1995), whereas the notion 'network organisation' is used to emphasise that a different logic exists compared to a simple network, described by Achrol (1997) as it holds a different *"... density, multiplicity, and reciprocity of ties and a shared value system defining membership roles and responsibilities ..."* The value logic is by Stabel and Fjeldstad (1998) used to define a set of three generic value configurations, whereas besides the classic value chain typology: value shops; and value network are presented.

- *Value shops models:* firms where value is created by mobilising resources and activities to resolve a particular customer problem.
- *Value network models:* firms that create value by facilitating a network relationship between their customers using a mediating technology.

Describing the differences between these network constellations, eight different parameters are used, among others: value creation logic; primary technology; business value system structure; and key cost drivers. It is suggested that the value chain analysis is exchanged with the value configuration analysis (Stabel and Fjeldstad 1998) to be able to make a competitive advantage analysis, though it is not elaborated how.

2.4.4 Describing network, stakeholders and the relations

The network structure and boundaries/scoping is important in understanding the network and describing changes therein (Möller and Rajala 2007; Allee 2000). Breaking down different relationships within and outside company boarders is done by categorising the relationships, bringing a context to different groups of relationships. Below are examples:

- Relationships within individual firms is referred to as internal relationship (Håkansson and Snehota 1995; Achrol 1997) or intra-organisational relationship (Cousins and Spekman 2003).

- Between two stakeholders externally is referred to as external relationship or inter-organisational/inter-firm relationship, intermarket (Achrol 1997), and a dyad (Rönnbäck 2002).

- Between more than two is referred to as a network, and specific if only three stakeholders are mentioned/involved it is coined a triad (Cakkol 2013).

- Characteristics of a relationship can be described through whether the relationship is direct or indirect, as an indirect relationship can have influence, or be necessary to be influenced also referred to as structural holes.

- Relationships are also defined through their position within the network (Windahl and Lakemond 2006), with examples like: vertical network (Achrol 1997) and horizontal network, upstream or down-stream relationships (Wise and Baumgartner 1999) or in-bound vs. out-bound (Baines et al. 2005), where all different terms are referring to the ecosystem as a sequential chain with a direction further away or closer to the customer.
- The position can also be named through the function the company has in a certain context, e.g. a broker, a bottleneck, etc. (Allee 2000).
- A relationship can be described through whether it is a receiver or transmitter of change (Halinen et al. 1999).
- Some describes the network by the goal, implicitly (Tidd et al. 1997) or explicitly, with examples like: opportunity networks (Achrol 1997), R&D networks, Innovation networks, standardisation networks, solution networks, cooperative (Cravens et al. 1993), marketing networks(Grönroos 1994), and distributions networks.
- Networks have been described based on the value logic within the network (Möller and Rajala 2007; Tidd et al. 1997). This can be seen very closely linked to the goal of the network; e.g. with the example of co-opetition networks by Zineldin (2004), where competing firms align differently (e.g. through a collaborative formation).
- The context in which the descriptions are used influence the names and distinctions; e.g. Service value network and service ecosystem (Basole and Rouse 2008). Also the use of PSS ecosystem within this research project refers to the value-logic of the system. Concerning the organisational structure, Cravens and Piercy (1994) and (Camarinha-Matos and Afsarmanesh 2006) use the descriptions virtual and hollow network, indicating that the organisation is spread geographically.
- Or by the contractual or legal bounds (formal contractual relations); Joint venture, Strategic alliance etc. (Tidd et al. 1997; Cravens et al. 1993). Informal ties (looser affiliation with a technology community).

2.4.5 Reflection of the literature foundation

The above have given insights into the state-of-the-art PSS literature, the four PSS dimensions, and hereafter a dive into the PSS ecosystem perspectives and lastly a focus on inter-organisatinoal partnerships and network management theories from extant research fields. This final section in the chapter summarises and presents the literature, pointing towards a need for increased focus on the ecosystem perspectives of PSS.

1) **It is broadly claimed that the value chain needs to be dissolved to design and maintain a performance based PSS**. Neely (2008) uses the term *The Global Value System* to emphasise that a PSS should approach the network as globally distributed, containing multiple and various stakeholders, who have to cooperate to ensure value in use of the PSS. Adding to this Basole and Rouse (2008) claim that products and services are provided to customers by value networks via complex processes, exchanges and relationships. PSS with integrated solutions brings an increased dependency on the actors within the business network (Windahl and Lakemond 2006).

    - The stakeholder network of a PSS is also outside the product chain – and hereby moves away from a classic view on resources.
    - Collaboration is needed within the development of PSS relationships, which bring challenges to also to enhance communication.
    - Development of partnerships and PSS solutions can occur simultaneously.
    - Operationalising the ecosystem perspectives for the PSS developer is sparse.
    - It is broadly argued that a network-based approach 'collaboration across product life phases' to development of PSS will increase the performance of the system.
    - The PSS ecosystem is also outside the Product Chain—and thereby moves away from the classic view on resources.
    - Multiple research fields point towards the necessity to approach companies as collaborative organisations. The value chain is argued by many scholars to be replaced with a system perspective.

2) **The description of the supplier's position in the value stream or value chain is argued to change** (Mont 2002; Windahl and Lakemond 2006), network relationships are important when delivering PSS and Johnson and Mena (2008) go so far as to claim that there is such a thing as a "servitised" supply chain, which differs greatly from a pure product chain. Along with the increased interdependency between suppliers, partners and customers, there is a need to create close cooperation, trust, and long-term relationships between the different stakeholders(Windahl 2007b). Davies (2004) claims that boundaries are changed and activities moved between stakeholders, and that the manufacturers move closer to the

customers' businesses. One way of doing this is argued to be through a customer-centric component in its organisation (Galbraith 2002). When describing the change in relationship, it often goes hand-in-hand with reflections on the need for the organisation to change accordingly.

- The change is inter- and intra-organisational, when changing business approach towards a more service-oriented business. In these cases, internal and external resources are closely combined in the PSS.
- The factors influencing the ecosystem is described by many and broadly distinguishes these in soft (cannot be designed) and hard factors (can be designed).
- The resource external and internal to the focal company needs to be closely combined in a PSS approach.
- The new relationship structure within and between the companies brings new complex processes of value creation.
- The value chain is argued by the majority of scholars to be dissolved and replaced with a system perspective.

3) **Strategic partnerships are mentioned as being needed, when moving towards a product/service-oriented business** (Wise and Baumgartner 1999; Davies et al. 2006). Bastl et al. (2012) claim that there is a tendency to oversimplify the effect that the change will have on the external relationships and present a study of how buyer/supplier relationship is affected by the adoption of a PSS approach. A similar study is presented by Baines et al. (2011), where the classic value chain is the point of reference to describe how companies use vertical integration to optimise for better PSS delivery. Cakkol (2013) uses the same framework as Bastl et al. (2012), but expands the relationship attributes. Both approaches are simplistic and do not contain an operational approach for the design or management of the relationships.

- Cooperation between the stakeholders taking part in PSS is important.
- Research points towards specific strategic partnerships as a necessity, and that unexploited partnership possibilities already exist.
- It is argued that there is a tendency to oversimplify the complexity, when moving towards are more service-oriented company.

4) **Despite the approach taken and despite the view of the stakeholders described by a value chain or a value system approach, many scholars claim a need for increased collaboration**. Additional to a need for changed relationships with external stakeholders, a specific focus is on the need for increased collaboration. This argument has its roots in different elements – one being caused by the services becoming more technologically sophisticated and firms' focus on their core capabilities. Multiple stakeholders in the networks must co-operate in the design and delivery (Neely et al. 2011). Handling network changes and building new relations require new competencies. Anderson et al. (2006) describe that when creating PSS (integrated solutions) it is key to combine value activities of multiple stakeholders, in order to achieve a "value-creating" end-product. The company needs system integrator capabilities (Davies et al. 2006), also claimed to be the most important competencies of a company.

    - There is a need for a multi-stakeholder approach, not just a focus on the customer, but broadly in the network.
    - Company network capabilities include the ability to navigate, adapt and control the network, which are seen as vital in any company development activity.
    - There is a need for being able to collaborate in distributed networks, as the network often exists globally.

5) **The methods and tools – many network mapping tools exists** and are trailled in the research field of PSS, providing step-by-step approaches and many different ways of representing the network. The terminology to use when navigating within the ecosystem Dimension of PSS is sparse and inconsistent. Most of the terms used relate to the old value chain concept and only a little to the ecosystem approach 'value system'. Many terms are used to describe connectedness in the PSS ecosystem: Network, partnership, relation, link, system etc. Influencing and orchestrating the network can be seen as a design activity.

    - Conceptual frameworks for strategic thinking connected to the ecosystem of PSS are developed, but none focus broadly on the network—but take point of departure in supplier/customer relationship.
    - PSS ecosystem factors influencing the 'value proposition' are found and provide a retrospective analysis of the influence the ecosystem had on the solution.

- The terminology to use when navigating within the ecosystem Dimension of PSS is sparse and inconsistent. Most of the terms used relate to the old value chain concept and only a little to the ecosystem approach 'value system'.

- Resistance from suppliers to enter a performance based PSS has been observed—as information and decision are not properly shared.

- Different frameworks exist to approach development of a PSS, but agreement is that iteration between PSS domains/components are a necessity.

- To be able to define new service activities, stakeholders within the product life phase need to be identified and their constellations revealed.

- Visualisation and representation techniques are essential to communicate at an early conceptualisation stage within a team activity.

- Being able to model PSS concepts while they are still abstract is fundamental

- Point of departure within a function 'value proposition' is argued to be the starting point of a PSS development activity.

- Studies bringing together suppliers for co-development of PSS solutions, where the development activity is described, have not been found.

6) **Research approaches:** Research studies focusing on the importance of the ecosystem within PSS development and operation were presented. Case studies are lacking where focus on ecosystem is approached from involving multiple stakeholders, and not just supplier/customer.

    - Research where the descriptive studies are validated are limited.

    - Studies that bring in-depth details to a PSS conceptualisation activity and analyse the outcome have not been found.

    - Company network capabilities are the ability to navigate, adapt to, and control the network, which are seen as vital in any company development activity.

    - Managing mechanism to orchestrate networks has not yet been found.

- The network terminology outside the PSS research field is also inconsistent—in all the different approaches to describe a relationship.
- Characteristics are used in many of the descriptions of networks: relationships, matrices, etc.
- Decision making tools for ecosystem integration are provided but provide only a limited approach for analysis to base the decision on.

2.5 Summary

The research field of PSS has been presented, by introducing the theoretical state-of-the-art for PSS development. The many scholars and research communities bring different approaches for PSS, also under different terms as; industrial solutions (Foote et al. 2001), service engineering (Tomiyama 2001), the most widely used description of a PSS is by Goedkoop et al. (1999) *"a marketable set of products and services jointly fulfilling a user's need."*. The sustainability and environmental concerns were summarised. Stahel's (2010) notion of the performance economy are vital to the research field, which principles are now broadly known and tried implemented by the now widely used concept '*circular economy'.* Motivation and possibilities in a service-orientated business were discussed, and PSS as a design object for conceptualisation were investigated, and finalised with an introduction and detailed description of the four PSS dimensions; value proposition, offering life cycle, user activity cycle and Ecosystem.

The next research section concerned PSS from an ecosystem perspective. Where existing frameworks where the ecosystem dimension of a PSS is presented were discussed, with examples as conceptual frameworks, like 'partnership based business model approach' (Matzen, 2009), 'a model for PSS development activities' (Tan, 2010) and the 'Solution Oriented Partnership' methodological framework (Manzini et al. 2004). These frameworks are theoretically prescriptive frameworks that bring the researcher and industry practitioner clarity to the ecosystem interconnectedness, with PSS development concerning business strategies and integrated product and service development. From the servitisation literature with focus on business and management literature, many transition frameworks describe the process from a manufacturer towards an integrated product/service-oriented business using the change in the ecosystem (intra- and inter-organisational) of the company. With examples like customer-supplier interface (Martinez), a value stream approach (Davies 2004), business process integration (Matthyssens and Vandenbempt 2008). Across all frameworks the majority of the frameworks with a focus on PSS ecosystem as in integrated part, were limited in the models focus on operational guidance for industry practitioners.

The chapter proceeded to present a literature review integrating also extant literature to the PSS field, from business and marketing research, focusing on the ecosystem perspectives of an organisation. This was acheived by focusing on three main areas: i) network representations; ii) network factors and influencers; iii) network elements and classification. The first-mentioned gave insight into the plethora of stakeholder network methods used in PSS, with many mapping and representation techniques and aims for each. The second mentioned presents the factors to be aware of when changing the organisation, with examples such as trust, commitment and sharing information. These are often split into hard (process/system) and soft (social). The framework by Windahl and Lakemond (2006) was presented, which brings six factors of importance to PSS development, five of which consider inter-organisational perspectives, i.e. strength of relationship, solutions impact on customer. The third mentioned literature focus gave insight into partnership models with a framework of how to develop inter-organisational relationships, where many of these state the importance of the inter-organisational relationship and claim that the capability to manage these relationships as the most important asset to any company. Network classifications were presented, which gave an introduction to how relationship and network classifications are made, which were found to be presented by matrices, excessive lists and by the value logics within the network.

The literature review revealed that various unique characteristics were used when detailing the need for a change in the transitioning process, presenting the elements of a partnership-based model or the classification of the different network types. The characteristics varied in number and complexity and no clear acceptance or convergence of a set of characteristics was observed during the study.

3.

Research foundation

3. Research approach

This chapter describes the research design used within this project. The methodological approach and research design are discussed, and a detailed description of each research stage of the project is provided, The research methods used for data collection and data analysis are elaborated, together with a breakdown of the research questions. A description of the research structure of the PROTEUS innovation consortium are provided, together with a reflection on the collaboration in the research team.

The research carried out in this project uses theory-building, based on close collaboration with industry. In this approach, the researcher participates in and facilitates development within the industry, simultaneously creating and testing normative support methods, plus leading different research topics.

This research project and in general the PROTEUS consortium set out to continue the theoretical foundation for PSS design, canalising this to industry through empirical investigation and internalising the findings from the industry field into the general academic discourse. According to (Tan 2010), PSS can be seen as a design of:

- PSS as a value proposition (design object perspective)
- PSS as a value creation (design process perspective)
- PSS as a business strategy (strategic management perspective)

The focus in this research project touches on all three areas. The objective is to investigate how to support companies in a network-based development approach to PSS, which strongly relies on the engineering product development activity and the organisation within which this takes place. This type of inquiry belongs to the academic field of *Design Research*. Design research concerns both engineering design (product focus) and product development (development activity focus), each of which are examined in this thesis. This research project seeks to investigate how companies can collaboratively develop and operate a PSS, for which reason the fields of social science (business research) are also relevant, particularly concerning the management of people to organise, reach and maintain certain goals.

Within design research, the aim is to improve design by improving the current design process, by acquiring knowledge from work practice, theorising, and contributing new design theories and other support elements to the field (Andreasen 2011).

" ... The most central behavioural characteristic of a design theory is that the theory leads to productive designing through the created mindset of the

designer and the models, methods and tools; i.e. that it raises the probability of results and creates a space of solutions ..." (Andreasen 2011)

Within this project, the industrial research object consisted of ten companies within the same industry branch, namely the Danish maritime branch. Andreasen (2011) illustrates the reasoning of design research (or Design Science) in Figure 9: Design Science, according to which this research project also can be described. The descriptive knowledge was made by multiple iterations between the actual workspace, empirical insights and theoretical foundation. This made the foundation for the prescriptive knowledge and the support tools developed, which was then brought back to the work practice for validation of its effect.

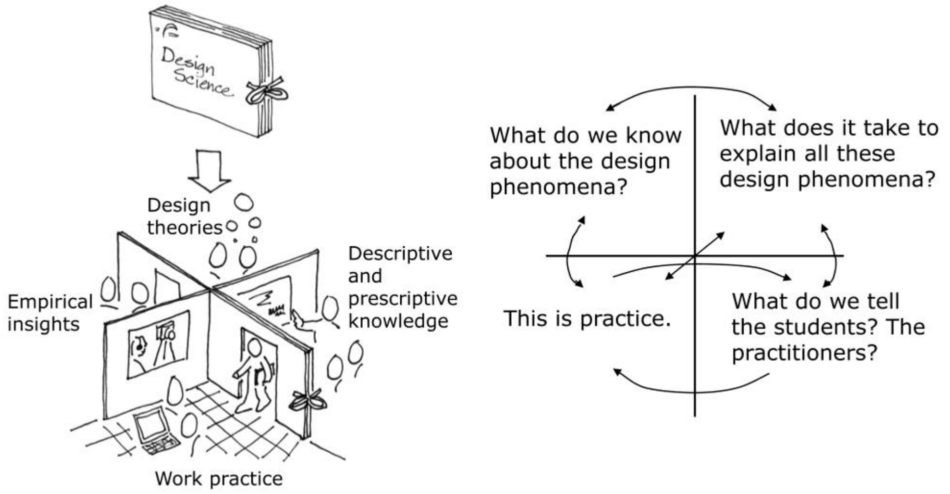


Figure 9: Design Science (Andreasen 2011)

3.1 Research strategy identification and research clarification

A research design is created by a range of choices of methods for data acquisition and data analysis that affects the reasoning for any insight created in the research project, which is why these must be carefully designed and reasoned upon during the development of the research design. Research can be described as exactly this: *"a methodological process of inquiry and investigation, with a view to increasing knowledge"* (Collis and Hussey 2009). A key decision for the methodology in this research is the use of an action research approach, which can be seen as an approach that allows support of social change, within various forms of social practice, through cooperation between practitioners and social scientists. Within this, action must be based on knowledge created by scientific fact-finding and where possible, be used to judge the effect of the action (Lewin 1946). This approach allows the researcher to take part in the phenomena being researched and in cooperation with practitioners in the field drive a change process. Action-research allows the researcher to interfere with that being researched by creation of appropriate arguments and evidence for extraction of any findings. " ... *Action research – in this* *process the researcher enters a real-world situation and aims both to improve it and acquire knowledge ..."* (Checkland and Holwell 1998). As the aim of this research project is to *support* the Danish maritime industry in a transition towards an integrated product/service-oriented business, the action research approach is appropriate. The phenomenon (the research object—the maritime industry) covers multiple areas of the organisation and also goes across companies. Besides this, a change from a product-oriented company to a product/service-oriented company has historically in other industries shown to be a ten-year process, which thus further complicates the change process. The action research approach allows the researcher to get in-depth knowledge across all companies, creating a preliminary diagnosis from which to create a plan for a change, initiate the change together with the companies, and support this continuously over a long-term period (in the case of the innovation consortium PROTEUS, a four-year period). Within this research project the strategy made it possible to instigate a change process through which the synergy between the companies, through knowledge sharing (and collaboration), could potentially speed up a PSS transition and increase the possibility of success.

Action research has been used for many years and has many names: action learning, action science, action inquiry, and participatory action research. What they all have in common is the critique of validation, as it is not possible to make the same replicability as in natural science (Checkland 1998). Attention to the link between the "*real problem situation*", the "*action in the situation*" and the "*reflection on the involvement*" must be made carefully, and this is highly influenced by the epistemological assumptions of the researcher.

To preserve the rigour of the research, and because the main research paradigm is within design research, the methodology is built on the Design Research Methodology (DRM) by Blessing and Chakrabarti (2009). The methodology allows a systematic approach for conducting design research, where the overall aim of Design research is: "... *to make design more effective and efficient in order to enable design practice to develop more successful products ..."* (Blessing and Chakrabarti 2009). That design research/design science is aimed at *improving* is also expressed as *"... the purpose of design science is to raise quality of designing and designs ..."* (Argyris and Schön 1989). This is accomplished by a focus on both the creation of *understanding* the phenomenon of design and the development and validation of *support* to improve design practice. The DRM framework therefore allows the researcher to generate insight into the design practice and by development of different support elements, to strive for a changed and improved design practice. The evaluation of the change is supported by development of a holistic model, illustrating the influencing factors of that being researched, the phenomenon. This model a 'reference model' mapping the influencing factors of the research object support the justification of any finding, because it represents the real-world situation before any intervention. To construct the research strategy, this model (making a graphical representation of the object under study representing all constructs and their relation) was used, together with the research question, to guide the research design. (model not included in the thesis) In chapter 1 the research goal and objective are described, and these correspond to the current situation and the desired situation.

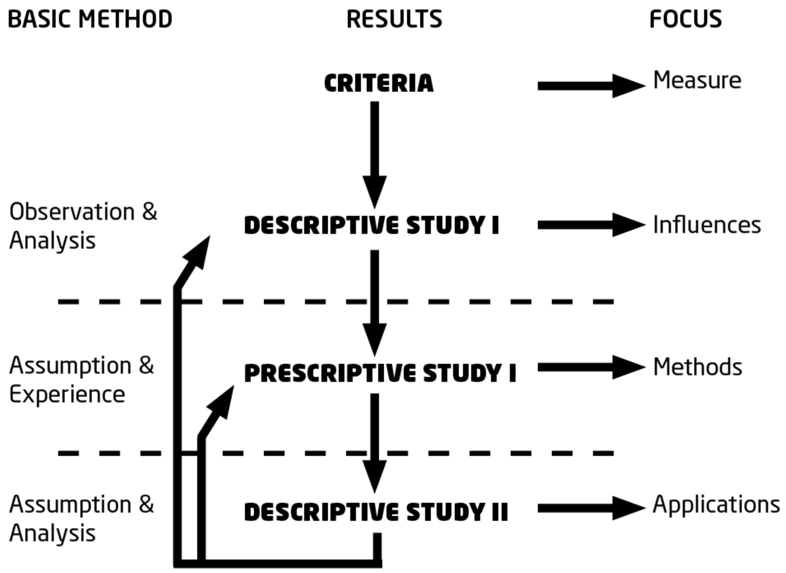


Figure 10: Design Research Methodology 'DRM' (Blessing & Chakrabarti, 2002)

Looking at the PSS as a collaborative system, which consists of many different stakeholders, it can be seen as social science. But as the product is a strong part of how the stakeholders act; the object of study is strongly within design research. The object of this study concerns how it is possible to support a PSS development and operation (e.g. strengthening the collaboration between the different stakeholders within the system). As mentioned previously, the intention of this research project is to strengthen the way in which industry develops and operates PSS, by approaching the challenges and possibilities that PSS presents, viewed from a particular PSS dimension namely the ecosystem perspective. The overall topic of interest:

- **Issue of interest**: The quality of PSS designs (in terms of ecosystem 'efficacy').
- **Activity and/or stage of the design process:** Synthesis and conceptualisation.
- **Area of application:** Maritime industry, technology development, and service process development. The context can be within manufacturing firms as well as service oriented companies (e.g. consultancies).

3.1.1 Literature foundation

The literature review continued throughout the entire research project, and can retrospectively be divided into three main phases:

- The explorative study of PSS, historical origin, state-of-the-art, definitions terms and typology. Building the general foundation for the research and stating the theoretical gap.
- PSS from an ecosystem perspective, and
- PSS with particular focus on inter-organisational relations.

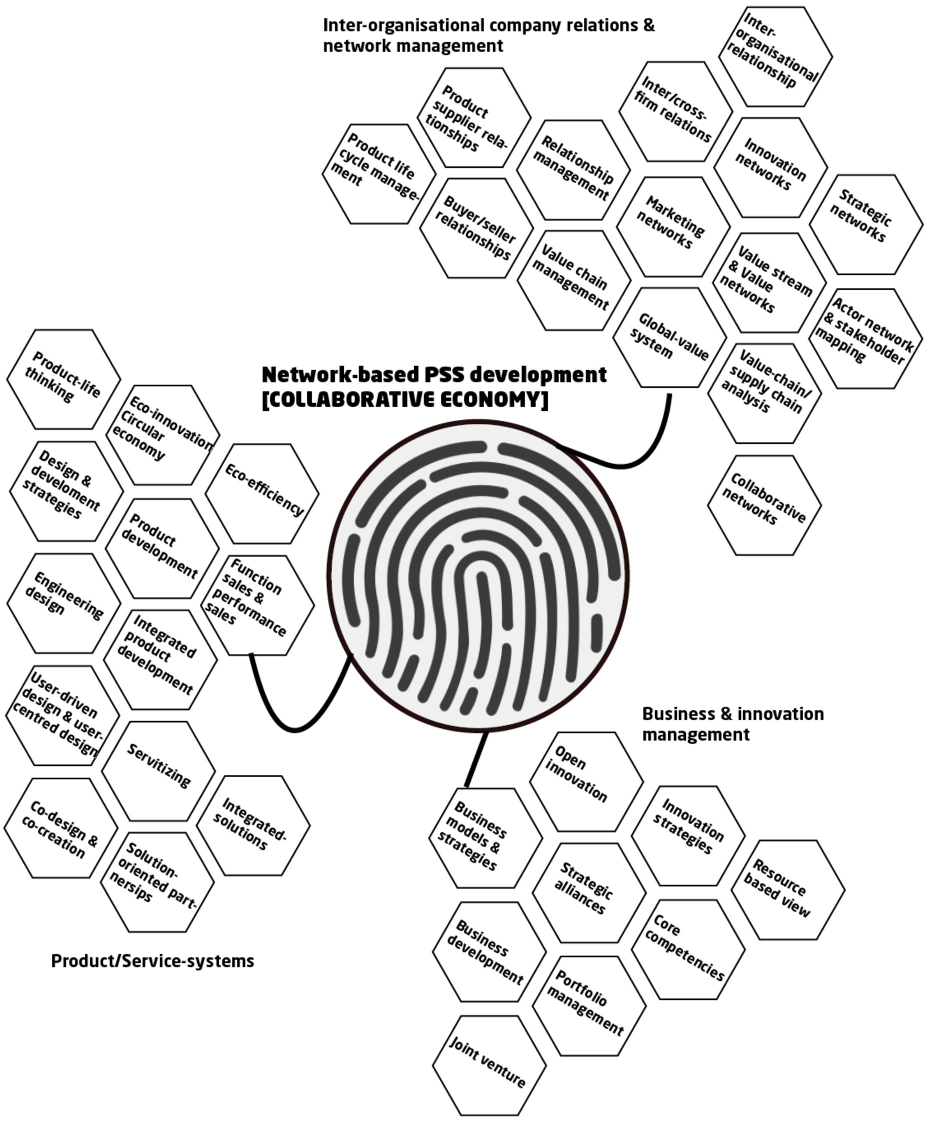


Figure 11: The literature review-print for this research project

Figure 11 gives an overview of the research fields and related strategy for the theoretical study. This research project had different theoretical research streams which composed the theoretical foundation for the research project. Besides 'Product/Service-systems' viewed from the Design Research paradigm, also literature within social science and business economics, constituted two larger areas of literature foundation; 'Inter-organisational company relations', and 'collaborative economy'.

The research in this project was also developed in close dialogue with other researchers, both via high-level academic conferences and through an extended research stay at a partner university, as listed below.

Academic discussions:

- 3rd CIRP IPS2 (Sweden)
- DESIGN 2010 (Croatia)
- ICED11 (Denmark)
- 4th CIRP IPS2 (Japan)
- Extended research stay (visiting scholar), Stanford University (USA)

3.1.2 Factors, success criteria and measures

To enable the creation of the research approach the following measures were decided upon. These measures create a condition for synthesis and conceptualisation. As we were looking at a time-related phenomenon – the increased PSS goodness – a comparative study was chosen to create an experiment, within which it was possible to control different parameters in the experiments. Based on the above, the following measures were in focus:

Basic measures:

- Taking into account multiple stakeholders.
- Awareness of the network.
- Multiple stakeholders conceptualise.

Success criteria:

- Increased competitiveness / increased profit.
- Increased network considerations within PSS development/ operation.

To evaluate the support developed a set of measurable success criteria was developed; these are listed and detailed in chapter 8.

3.1.3 The innovation consortium: PROTEUS

The purpose of the project was to simultaneously create research insights and innovation results over a prolonged (4-year) collaborative project, consisting of representatives from Danish research institutions, a technical service partner (consultancy), international university partners, and ten maritime companies. The ten participating companies in the project were interested in understanding, through examples, how to effectively and systematically integrate service development into their product development and business creation processes. The unique quality of PROTEUS was that it seized a unique opportunity to substantially increase both industry- and research-related knowledge of how to create technical solutions and new ways of doing business that integrate products and services as parts of integrated offerings to the market. PROTEUS was the first PSS research project to focus on an entire industry branch. The name of the consortium, PROTEUS, was also an apt title, as it is the name of a mythological Greek sea-god, a symbol of adaptability in the face of the changing nature of the sea! The innovation consortium sought to investigate and implement product/service-system strategies at a number of levels in the participating companies and to make these insights generic towards the end of the project. PROTEUS was organised into five work packages see Figure 13, spanning a broad approach to the research, from understanding the servitisation needs and possibilities of the whole branch, through understanding the network potential of collaborating to provide PSS solutions, to actually building the PSS concept and business model (McAloone et al. 2010a). This PhD project was based mainly on work package 2: Network-based development models, but also contributed to work package 5, with methods for communicating PSS approaches in industry and to work package 1, with a focus on identifying the PSS readiness within the industry.

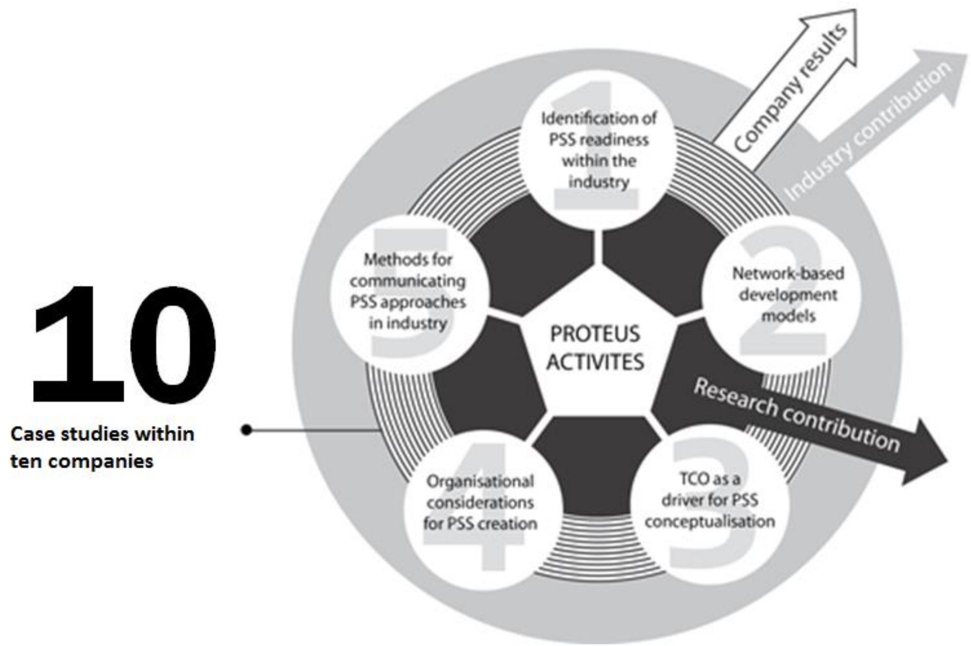


Figure 13: PROTEUS research consortia - five work packages

3.1.4 The Research questions and their constructs

Before being able to carry out the research design and verify whether the research questions could be answered within the frame of this research project, the *constructs* used in the questions had to be detailed and described. The reason for this was to investigate if the constructs could be measured, plus to establish which methods were suitable for use in the research design. Detailing each construct, by giving it an operational definition, made it possible to empirically establish whether this phenomenon could be measured (Blessing and Chakrabarti 2009, 95). See the research questions in Table 9.

Table 9: Research questions and the research stages according to DRM.

Research questions and research stages						
	RC	**DS1.1**	**DS1.2**	**PS1.1**	**PS1.2**	**DS2**
RQ1: Through what terms and models can PSS offerings be described in order to support their successful synthesis?	•	•	•			
RQ2: How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?			•	•		
RQ3: How can a PSS conceptualisation activity allow an inherent network approach for co-development of PSS design?					•	•

3.2 Reflection on the research design

During the project, interaction with the ten participating companies took place over the course of four years in multiple ways, at many different levels, and with varying goals. The research project's first explorative study, which generated insight into the industry and the phenomena herein (the real-world situation) made use of semi-structured interviews, as these could lead the interview in directions of interest by both the interviewee and the interviewer. This can be seen as the least influencing and intervening, but it is important to acknowledge the effect *thinking and arguing* about subjects can actually have because any change can be seen as a mental abstraction at the meta-level (Checkland 1998). A survey based on the explorative study allowed a comparison across companies and was in this sense non-intervening. Hereafter, bi-annual meetings, student projects, conferences, single-person interviews, and an in-depth case study for the actual test of the developed support from this project increased the involvement with and verification by industry.

As the above indicates, the methodology chosen for this project is built on a mixed-methods approach. The research is both quantitative and qualitative, which is an emerging research paradigm. Without going into much in-depth with the new paradigm, the mixed-methods approach has its strength in getting the best from two worlds (Johnson and Onwuegbuzie 2004). Neely (2007) criticised the "PSS/Servitisation" research field for relying on only single case studies. This prompted him to create a longitudinal study through collecting large scale data sets on manufacturing and their adoption of PSS. The PROTEUS consortium contributed to this, as multiple case studies were made within the same context, relying on both quantitative and qualitative data sets of small and large scale.

Continuous iteration between different analysis methods has been used throughout the research project, with the use of iterative exploration as a backbone. This was described by Robson (1993) as the "iterative exploration method" and by Yin (2009) as pattern-matching strategy for analysis. These two approaches has been conducted using different methods, such as the KJ method (Martin and Hanington 2012) and affinity diagramming (Martin and Hanington 2012).

3.2.1 Case study as main research method

Overall, the research project included three different case studies, which will be detailed in the following section. Yin (2009) describes a case study as *a research strategy* within social science research, with different case study types to select. Case studies are chosen to: "... *Investigate a contemporary phenomenon within is real-life context. Especially when- the boundaries between phenomenon and context are not clearly evident ..." (Yin 2009)*. Matzen (2009) claimed that product development, service development, and operation cannot be separated from the contextual setting. This idea corresponds to Yin (2009) description above.

"... The phenomenon of 'product development' cannot be divorced from its contextual setting within the firm, as it is influenced and relies on informational and resource exchange with all other company functions. It might not even be explicitly evident to the participating actors that they are conducting development work ..." (Matzen 2009, 74)

In this research project, case studies will be described as an overall method within the research design, where different sub-methods are used in each case study. The research design uses a mixed-method approach where a combination is made from qualitative and quantitative research. SeeTable 11 for an overview of the two types of research.

Table 10: The characteristics of qualitative and quantitative research [Creswell 2007]

Qualitative research	Quantitative research
Mainly used to develop an insight into the nature of a specific subject	Often used to verify a hypothesis
Often involves a deeper analysis that helps build an understanding of how elements are arranged	Done by measuring, testing or categorising elements in ordering to describe or explain something

What characterises the case studies is the use of multiple case study investigators, together with the use of a shared case study database throughout the research project.

Case study 1: The first study was a purely 'qualitative descriptive exploratory multiple' case study. The study was jointly conducted by the research team by visiting all ten PROTEUS companies. The aim of this study was to examine and understand the research object and construct an "as-near-as-possible" picture of the phenomena. This was done company-by-company through investigating topics, such as organisational structure, culture, interplay between departments, development processes, development methods, PS-offerings, customer interventions, employee capabilities, business strategies, industry challenges, and more. With a main aim to uncover their experiences with PSS development and operation. The study can be described as a rich empirical description covering a complex and multifaceted subject, and was carried out by Yin (2009) description of a "multiple case study" approach with each their own "embedded unit of analysis."

Case study 2: Two in-depth single case studies and a "comparative case study" were set up like an experiment and conducted with MAN PrimeServ Frederikshavn and Alfa Laval Aalborg. Described by Yin (2009) framework for case studies, each company within this case study was approached as an "embedded unit of analysis," while each development workshop was seen as a "single unit of analysis." In total, this study covered four elements of analysis for use in the explanatory evaluation. It had a strong participatory character with a set of workshops, meetings, together with an established platform from which collaboration was initiated between the companies. The case study consisted of different stages as follows:

- Descriptive: portray an accurate profile of each company with semi-structured interviews within both companies; creation of representation models.
- Prescriptive: Two workshops, one in each company.
- Prescriptive: A shared workshop—both companies together.
- Explanatory: Evaluation of the outcomes from the workshops.

This study was a combination of qualitative and quantitative research. A comprehensive case study protocol was used throughout the comparative case study due to the length and details of the study. The people involved in the study held varied set of positions, experience levels, and age and represented various views from the companies. See Table 11 for an overview of which profiles were involved.

Case study 3: This study is not thoroughly described in the thesis but was nonetheless important to the research design and this project. The study aimed to investigate best practice in other industries and involved three companies: Volvo Aero, MAN Truck & Bus, and BASF. The study focused on five different elements, including motivation, transition process, challenges, business model, and PSS offerings. The findings from this study were disseminated to industry through the PROTEUS workbook series

Workbook #2; the PSS case book (Neugebauer et al. 2012), and were a key theme for the second PROTEUS conference.

Student case studies: Case studies were also conducted by multiple Bachelor and Master Students during the consortium and were mostly action-based studies. With a total of 13 projects, 22 students and a total use of 42 company studies all within the maritime branch. All material can be found on the PROTEUS website. The author of this thesis acted as co-supervisor on several of the projects. The student projects were planned in clusters to allow the students to triangulate their findings and to build synergies between the different groups of students.

Table 11: Overview of studies made by students

Project name	Company	Type	Students	When
Application and Validation of Service CAD in the Maritime Branch	MAN Diesel & Turbo A/S	Bachelor (DTU)	1	February 2014
An exploration of the customer's perspective of Product/Service-Systems	TORM A/S.	Master (DTU)	2	July 2013
Service Level Agreement Prototyping from a PSS Viewpoint: The Case of Emerson MTM	Emerson MTM	Bachelor (DTU)	2	June 2013
Shared Representations for Supporting Open Innovation: A Case Study in the Maritime Industry	All PROTEUS companies	Master (DTU)	1	October 2012
Co-creating a sustainability strategy in a Product/Service-System value-based network of stakeholders	Novenco Fire Fighting A/S	Master (BTH)	3	June 2012
Development of archetypical Product/Service-System approaches for the maritime industry	All PROTEUS companies	Master (DTU)	1	April 2012
Development of a service model for an engineering consultancy in the maritime branch	d's Register ODS	Master (DTU)	2	March 2012
Understanding Customer Relationships in a Product Service System	MAN PrimeServ Frederikshavn and Alfa Laval Aalborg	Master (CBS)	1	November 2011
Increasing Customer Retention Through the Offerings of a PSS at Emerson MTM	Emerson MTM	Master (CBS)	1	June 2011
Development of Technical Service as a business area for a product-oriented company	Hempel	Master (DTU)	1	Septembe r 2011
Development of PSS for Novenco	Novenco Fire Fighting	Bachelor	1	

Fire Fighting A/S	A/S.	(DTU)		
Tool For Development Of Service In The Danish Ship Industry	ACTA, Emerson MTM, Novenco, Novenco FF, YIT, Odense shipyard, Meridian, Carras and Danish Maritime.	Bachelor (DTU)	2	June 2009
PSS for the maritime industry	Emerson MTM former Damcos , YIT and Danish Maritime.	Bachelor (DTU)	4	June 2006
TOTAL (22 students/ 13 projects)	42 company cases	DTU, CBS and BTH	22	2006-2014

3.2.2 Interview

Interviews were used throughout the research project as a primary research method. Multiple times during the PROTEUS consortium, we conducted open-ended interviews via phone with all participating companies in order to preserve momentum and get insights into current developments, changes and motivations of the companies. This was vital because during the consortium a few people departed or changed roles at the companies. Therefore, we developed a strategy to keep a strong connection to the companies by multiple good relationships.

Table 12: Types of interview questions

Type of question	Useful for	Not useful for
Open questions (e.g. tell me what happened when…)	Most openings to explore and gather broad information	Very talkative people
Closed questions (E.g. who did you consult?)	Getting factual information	Getting broad information
Probes (e.g. what happened next?)	Establishing sequence of events or gathering details	Exploring sensitive events
Hypothetical questions (e.g. what might happen that could change your opinion?)	Encouraging broader thinking	Situations beyond the interviewee's scope
Comparison questions (e.g. do you prefer weekly or fortnightly team meetings?)	Exploring needs and values	Unrealistic alternatives
Summary questions (e.g. So, am I right in thinking that the main issue are…?)	Avoiding ambiguity, validating data and linking answers	Premature or frequent use
Multiple questions (more than one in a sentence)	Never useful	Never useful

" … One aim of the interview is to develop an understanding of the respondent's world so that the researcher might influence it, either independently or collaboratively …" (Business Research p. 144). This quote

describes the main aim of the interviews within this research project as this applies for DS1.1, DS1.2, and DS2.

3.2.3 Documentation and archival records

Within the research project, many different sources of information and data have been gathered through documents and archival records. Some of the key data collection methods included:

- Internal confidential documents: Organisational diagrams; workflow charts; PP Presentations of company strategy; standard service agreements; actual service agreements; service claims; pricing schemes for service engineers; service update letters (service letters); warranty agreements; sub-supplier manuals; and many more.
- External documents: PR articles and videos; product brochures; product information documents; technical drawings of products; public service descriptions; annual reports; and industry relevant newspapers.
- Visual data: Video; photography.

Each company granted access to intranets for the comparative case study. For the single case studies, the material varied in type and richness of empirical data, reflecting the size and type of the organisation. Getting access to unique information was strengthened by the associated student research projects.

3.2.4 Data presentation

The different data gatherings were documented through different methods:

- Audio/video recordings always with name/department and context attached to filename.
- Photographs.
- Online internal database (PROTEUS).
- Logbook of events containing a template for capturing data.
- Comparative case study: The logbook contained all activities and reflections during the study. Every entry was dated with brief descriptions for use in meetings and interviews at the companies.
- Representations: Many of the methods used in the research project, such as flow diagrams; stakeholder network; user activity cycles; and more were used throughout the project as documentation and as a medium for validation by interacting with industry practitioners.

In the research team: During the consortium, the research team used many methods for sharing data collections, analysis, and in general conducting project management. “Stakeholder management” was conducted mainly through advanced use of Outlook by logging contact information and company interaction throughout the research project. This ensured thorough documentation and ease of tracking research progress. Weekly meetings in the research group were used for status, updates, and to present and share data and findings, and each of these meeting included a summary. For all meetings and visits to companies and organisations in the research project, summaries were provided for the team to share insights. The research group also tried different approaches to maintain good relations with the companies. For example, each company was assigned a dedicated researcher. These changed during the years, but the practice was effective in supporting and aligning company interaction with the research group.

Narratives were used in the research project. Each company was assigned a “persona” containing core features and details, which developed during the research project. This was used in the early phases of the explorative study in DS1 to distinguish between the many companies in PROTEUS and stakeholders involved and to enable quick memory download of details and findings during discussions and analysis activities.

During the research project, data collection and data analysis triangulation were used throughout. Flick (2014) presents four different triangulations methods (based on the work of Denzin in the *The Research Act* (1989): i) methodological triangulation; ii) data triangulation; iii) theory triangulation and investigator triangulation, all of which have been used in the project. Triangulation was first a concept for validating results but has increasingly shifted towards a method for enriching and strengthening knowledge (Flick 2014, 183).

3.2.5 Direct observation and participant observation

Participatory observation: Multiple methods of observation have been used throughout the research project. Data has been collected by direct observation and guided tours at all the companies within the PROTEUS consortium. Visits to secondary stakeholders within the industry also provided opportunity for direct observation; e.g. a visit to a Danish ferry shipowner and a visit to the now closed shipyard, OSS, with a ship in dry-dock during maintenance activities.

Biannual meetings: During the project, several biannual meetings were held, and all the PROTEUS companies were invited. These meetings allowed presenting results and establish discussion and feedback. A main aim of these meetings was to combine one-way presentations and workshop formats to always encourage dialogue and strengthen relations between the companies. Approximately every half year such meetings took place.

Focus group: These meetings were facilitated by the researchers to bring together industry practitioners with a shared focus or goal. For example, at the biannual meeting a group was established in the identified interest area of *proactive services*. The focus groups were planned and coordinated to occur on the same dates as the biannual meetings.

Industry conferences: Two large conferences had several aims: i) disseminating results; ii) get broad feedback from across the industry; iii) implementing an understanding of PSS and the urgency of this within the industry; iv) strengthening dialogue and relations between industry practitioners. Two important characteristics of the conferences were to invite a speaker to present best practices from other industries and presentations from other stakeholders in the industry, such as shipowners. Refer to the PROTEUS website: www.proteus.dtu.dk. The first conference had the title: *Servitising Industry: Best Practice, Next Practise – setting a course for the maritime industry.* The second “closing conference” was called *World-Class Servitisation: Methods, Cases and Partnerships – completing the PS toolbox with the maritime industry*. A total of 180 participants took part in the conferences, with approximately 80% of these being industry practitioners.

3.3 Research design described following DRM

This section will describe each research stage, see an overview in Table 13. The research design can be viewed in two key parts in connection to the interaction with the industry practitioners.

- In part 1; Research Clarification and Descriptive study 1 and Prescriptive study 1.1, the research object is approached by including all companies.
- In part 2; Descriptive study 2 is focused primarily on a relationship between two companies where the developed support in Prescriptive study 1.2 is tested and evaluated.

This section gives an overview of methods applied in the research project. The research strategy and justification of the different methods used will be detailed. The mixed-methods approach (Johnson and Onwuegbuzie 2004) was applied in nearly all stages of the research process, and this key approach with a strong triangulation and critical rationalism ensured the validity of the research.

3.3.1 The research design in two dimensions

The research design can be viewed arranged in terms of two dimensions: i) time; and ii) comparison. Refer to Figure 14. This research project has several research decisions that can be represented in this figure. The research stages are distinguished in many of the areas from single case studies to comparative studies, as illustrated in the upper right corner, the PS typology was developed, with use of multiple single cases in a longitudinal study. The lower middle was a platform for the comparative case study, developing the ecosystem PSS tool.

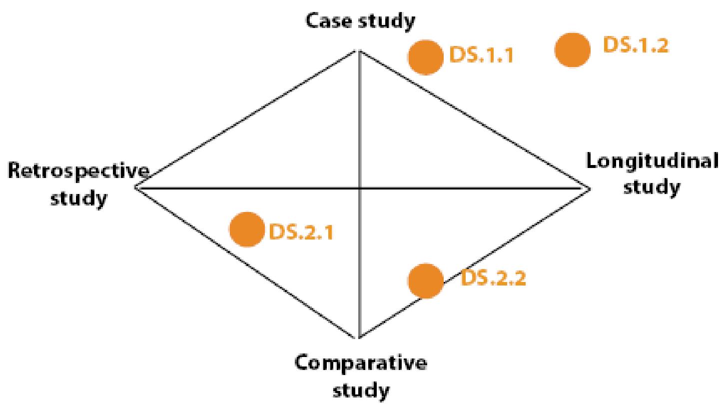


Figure 14: Basic Designs in Qualitative Research – modified model adapted from (Flick 2014, 130)

Table 13: Overview of research stages and research design and methods.

Phase	RQ	Data acquisition method / *type*	Empirical base: *Entities/ participants/time*	Data analysis method / *type*
Descriptive study – Research question 1				
		Case studies / *Qualitative descriptive explorative multiple case study*	10 entities	
		Case study / *longitudinal case study*	1 entity	
		Case studies / *Best practice case study*	3 entities	
RQ + DS 1.1	RQ1	**Interviews** / *open-ended:* Explorative + explanative	10 entities (25 people) approx. 30 hours	Pattern matching strategy and iterative exploration / *KJ method*
DS 1.2	RQ1	**Interviews** / *Structured Interviews* (best practice study)	3 entities (4 people) approx. 6 hours	Data triangulation, Theory triangulation Investigator triangulation
DS 1.2	RQ1	**Interviews** / *survey*: semi-structured + structured	10 entities (20 people) approx. 25 hours	

DS 1.1 **DS 1.2**	RQ1	**Literature study /** comprehensive		Iterative exploration
		Survey /E-mail survey	10 entities (10 people)	Longitudinal comparison
Prescriptive study 1 - Research question 2 and Research question 3				
PS 1.1	RQ2	**Literature study /** review-based	Iterative exploration	
PS 1.2	RQ3	**Literature study**	Pattern matching strategy and iterative exploration */ Affinity diagramming + roll the snowball* Data triangulation, theory triangulation.	
Descriptive study 2 – Research question 3				
DS 2.1	RQ3	**Case study /** *comparative case study*	1 entity	
DS 2.1	RQ3	**Interviews /** *Semi-structured + retrospective studies*/ Scoping comparative case study	8 entities(12 people) Approx. 8,5 hours	Data triangulation, Theory triangulation, investigator triangulation
DS 2.1	RQ3	**Interviews** /*Semi-structured + retrospective studies* / Scoping comparative case study	12 (14 people) approx. 15 hours	
DS 2.2	RQ3	**Direct observation and participant observation** / *development workshops*	3 (40 people) approx. 20 hours	Analytical generalisation
DS 2.2	RQ3	**Evaluation /** analytical generalisation		

Figure 15 is a visualisation of the research stages, illustrated by highlighting the main research elements. The figure particular visualise the interventions with the industry throughout the research project. In the descriptive study 1, all of the ten companies were involved, where in descriptive study 2, two companies were selected and involved. In the figure the letter A, refers to MAN PrimeServ Frederikshavn and the letter B refers to Alfa Laval Aalborg. ['W1A' = Workshop 1 at company A. 'in2A' = Second interview round at company A].

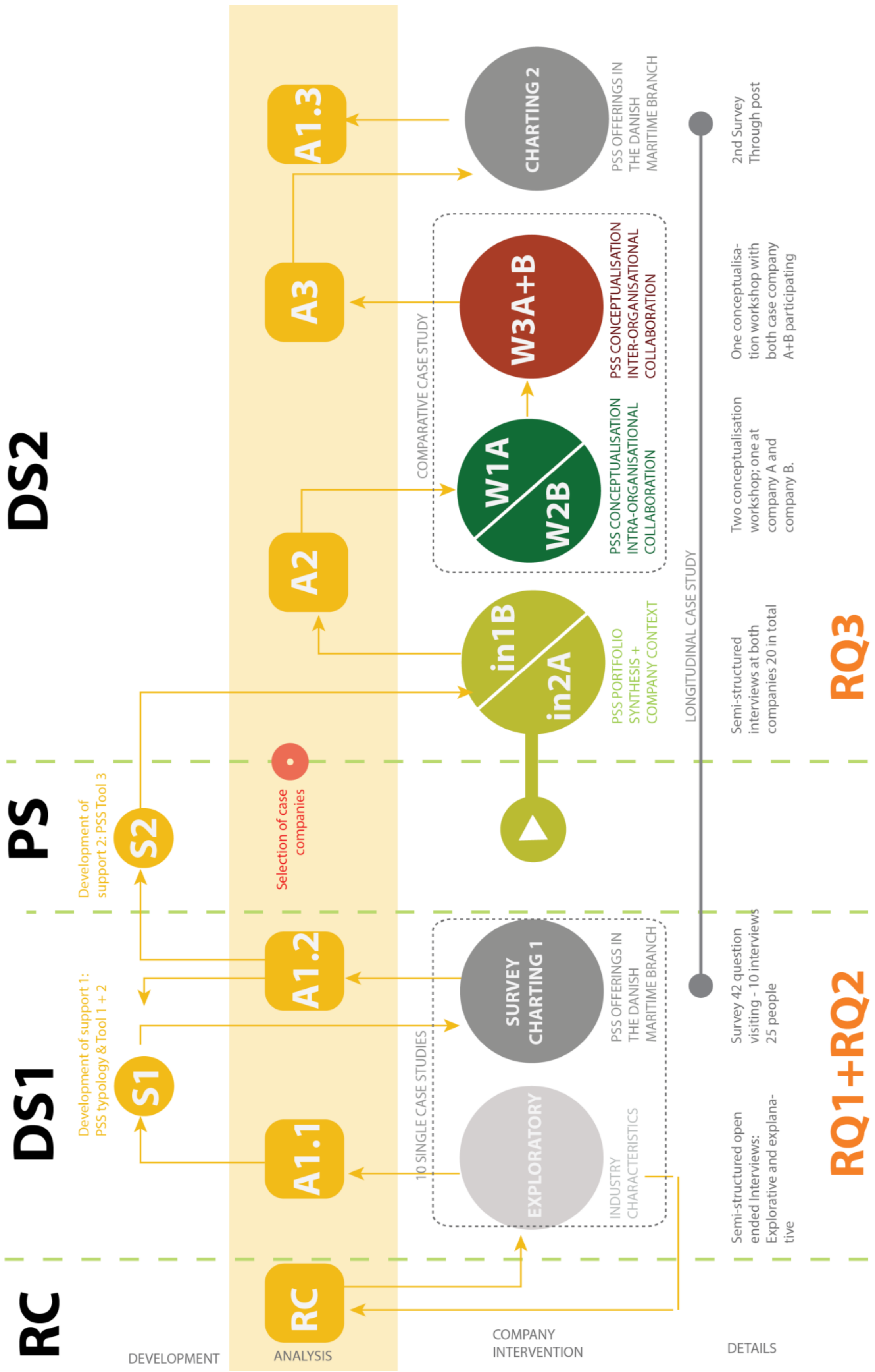


Figure 15: Research phases illustrated

3.3.2 Research clarification

The research clarification process was conducted iteratively, defining a set of research goals and questions and thereafter adjusting these during and after the descriptive study 1. A preliminary literature study based on state-of-the-art PSS research, combined with discussions with industry practitioners and researchers supported the research clarification process and the literature study throughout the research project.

3.3.3 Descriptive study 1

Descriptive study 1.1

This stage within the research project dealt with how to get an in-depth understanding of the industrial research object (the Danish maritime industry). This was done through an explorative and explanatory study of ten individual case studies with open-ended interviews at each of the companies. Each company was visited by two to three researchers, and two to four interviewees from the companies took part. The visits lasted two to three hours. At each visit, a tour of the company was conducted to observe the facilities and culture, including production facilities, production, stock, and quality testing. Different departments were introduced to the researchers. This gave a strengthened insight and understanding of each company. Primarily open-ended questions led the interviews and were thereafter strengthened and elaborated on by the use of *closed, probing* and *comparative questions* (see Table 12) In this way, the respondent became an informant as she/he described events beyond the knowledge of the interviewer (Yin 2009). The interviews were modelled after the interview method termed the "ethnographic interview" by Spradley (1979, 58) and emphasised the importance of the interviewee being able to speak their own language. This particular stage was also vital in the sense that it was used to align research and industry goals, to establish a sound platform from which expectations from the industry could be managed throughout the whole period of the PROTEUS Innovation consortium.

The empirical findings were articulated by the use of arbitrary categories and triangulation. This analysis method of iterative exploration and pattern-matching strategy was used as a consensus building activity in the research group. The KJ method supports the very early phases of analysis, and this was used to analyse the data collected. The method supports "meaningful grouping of ideas from a raw list" and guides the early synthesis without preconceptions because grouping appears from the data and not due to pre-ordinated categories. This was used to identify trends and an in-depth understanding of the industry as a whole and to extract a strong industry foundation, as presented in Chapter 4 – Industrial research context p. 93. In this analysis, the use of multiple data sources (data collection methods) was applied and included sources such as internal and external documents from each company, public annual reports from the industry, and scientific work as articles. The findings were compiled and presented in a confidential industry analysis report. A public version of this was presented via *Workbook #1 Maritime Branch Analysis by* (Mougaard et al. 2013). Both reports were used by the research group to establish a shared understanding of the object of study. Throughout Descriptive study 1, a literature review was conducted. Within the first stage of the descriptive study, the objective was to gain a solid understanding of existing knowledge within the field of PSS and the affiliated research fields.

Descriptive study 1.2

The second stage of the first descriptive study was aimed at creating a *support* a tool to support successful synthesis of PSS offerings within an industry branch. Aiming to answer Research Question 1: *Through what terms and models can PSS offerings be described in order to support their successful synthesis?*

This research stage builds directly on the descriptive knowledge generated from the industry foundation and understanding; without the in-depth characteristics of the industry, the development of the typology would have had its origin from literature and not from a strong iteration between real-world and theory building.

This research stage simultaneously provided understanding and clarity of the participating companies' (object of study) current level of product/service offerings. Revealing the company's current servitisation level and indicating a maturity level of each of the companies. The industry specific PSS offering typology was developed by triangulation, where the researcher had multiple iterations between empirical insights, work practice, theoretical constructs, and descriptive and prescriptive knowledge. Onsite visits to all companies formed the basis for the knowledge used in the analysis. The mapping was aimed at giving the research group detailed insight "descriptive knowledge" into the work practice.

In building the service typology, multiple iterations were made, with the key method of structured interviews, which resulted in the charting of the industry service level. The structured interviews used a survey with a set of specific questions resulting in a range of answers which is predetermined (Yin 2009). This interview method differs from the open-ended interview in DS.1.1, with the interviewee being encouraged to reflect on their own company context in a language "typology" designed by the interviewer. The sample size for this study was 20 participants covering a total time spent of approximately 25 hours at the companies. During each visit, two researchers participated in the interview, with one taking the role of note taker and one as facilitator. The author acted in all interviews as facilitator, and the role of note-taker was split across the PROTEUS research team to ensure broad continuous interaction within the group, as well as establishing a sound platform for researcher triangulation in the synthesis of the charting.

Also when building the service typology, multiple iterations were made, where data between the companies were triangulated by comparing the perceptions of the different offerings between the companies and also between industry practitioners within each company, adjusting the typology accordingly, in order to best match the industry branch.

Descriptive study 1 was finalised by constructing the *Reference model;* which represents the existing situation and describes a desired situation of the research object. Based on this model research criterion, factors and success criteria for design and support could be selected.

3.3.4 Prescriptive study

Prescriptive study 1.1

The first prescriptive study 1.1 aimed at answering research question 2: *How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?* Two conceptualisation tools (PSS tool 1; Cards and PSS tool 2: Configurator) were developed from theoretical knowledge gained from the literature study on existing frameworks used in development of a PSS strategy (transition) and listings and categorisations of service offerings across multiple research fields. Based on this, the typology got transformed and developed into different representations with guidance from several theoretical frameworks on: i) overview; ii) visualisation; iii) boundary objects; and iv) design objects.

After defining PSS conceptualisation and developing the two PSS tools, this research stage was finalised by introducing a new theoretical construct – the PSS Concept Elements (PSS CE).

Prescriptive study 1.2

The development of *the support* was done by a systematic literature study, based on a review-based descriptive study, as there was no industrial empirical evidence and no continuous evaluation with the companies. The descriptive study 1 can be described as being to slowly to transform into a prescriptive study, where prescriptive study 1.1 can be said to be based on a comprehensive review-based DS (as continuous iterations are made with industry), and the prescriptive study 2.2 occured in parallel with PS.2.1. The main research methods used to develop the support are affinity diagramming, and iterative exploration. (see detailed description in chapter 5)

The development process lead to the PSS tool 3 named PEC (Product/Service-System Ecosystem Characteristics), which can be used in PSS conceptualisation. This tool was developed to be suitable for the PSS conceptualisation framework tested during the PROTEUS consortium. The prescriptive study finalised with the development of the evaluation of the *intended support*, the comparative case study, together with a systematic process to validate and synthesise the effect of the implemented support within the comparative case study.

3.3.5 Descriptive study 2

Descriptive study 2.1

Descriptive study 2.1 consisted of two in-depth single case studies, by use of a series of semi-structured employee interviews at each of the two companies, to gain thorough understanding of the context within which the comparative case study took place. The aim of this study can be described in several key elements:

1. The interviews gave detailed insight into the challenges, progress, and readiness of the case companies in connection to PSS development and operation, resulting in several embedded units of analysis within each case. Creating a strong and comprehensive understanding of each participating company.
2. The study allowed for development of the representation models to use in the company workshops, which was also used as boundary objects between industry practitioner and researcher for data acquisition.
3. The interviews established a strong relationship between each company from which trust and commitment increased the likelihood of full implementation of the comparative case study.

The interviews were semi-structured with respectively 14 and 12 interviewees in each company. These covered functions such as: product developers; service technicians; warranty managers; supply chain managers; spare parts managers; service analysts; business developers; academy educators; and many more. Interviews were conducted with the aim of retrospective studies of collaborative projects where one or more of the PROTEUS companies had been involved. Looking back at previous experience and historic events gave valuable insight into the industry and into the research object. Multiple projects had been conducted with a focus on energy efficiency, such as with: Green Ship of the Future; Project Green Ship; and the Danish Maritime Retrofit Project.

The sample size of these interviews was 26 interviewees, and the duration of the interviews lasted approximately 1–1.5 hours in each company, refer to Table 14 for an overview of all interviewees and their function in the company. For the interview carried out at MAN PrimeServ Frederikshavn, a co-researcher (a Masters student from Copenhagen Business School) participated in the interviews with one interviewee per interview and with the questioning mainly lead by the author. Half of the interviews at Alfa Laval Aalborg were conducted solely by the author, with two interviewees per interview, creating a strong discussion of the answer. This method might have 1) biased the answers or 2) strengthened the answers as each interviewee had different functions within the company. The rest of the interviews at Alfa Laval Aalborg were conducted by the author and a co-researcher from the PROTEUS team and involved one interviewee per interview.

Table 14: Overview of profiles involved in the; Comparative case study. The letter I = Interviews. The letter W = Workshop.

Involved stakeholders from each case company. I = Interview and W = Workshop		I	W
MAN PrimeServ Frederikshavn			
	Senior Manager head of Propulsion / Propulsion aftersales	●	●
	Business developer	●	●
	Manager Project & Retrofit (previously head of Warranty &	●	●
	Sales / Project & Retrofit		●
	Sales / Project & Retrofit		●
	Head of Service Centre DK	●	●
	Service Annalists / Propulsion - Spare Parts and Technical Service	●	
	Service engineer / Service Centre	●	
	R&D Project engineer / Retrofit	●	
	R&D Project engineer / Retrofit	●	●
	Senior manager / Order Processing	●	
	Head of Academia / Propulsion Academia	●	
	Manager of SCM / Supply Chain Management	●	
	Project engineer / Aftersales & Project	●	
	Project engineer / Aftersales & Project	●	
	Sales senior manager / Europe group sales	●	
	Not defined…		●
Total		**14**	**8**
Alfa Laval Aalborg			
	General Manager / Marine & Diesel System – Parts & Service	●	●
	Market unit manager / Parts	●	●
	Service coordinator + Support engineer	●	●
	Lead buyer / Supply Chain Management	●	
	Manager / Repair sales & Order execution	●	●
	Team Leader / LSFO upgrade	●	●
	Guarantee engineer / guarantee	●	
	Area Sales Manager / New boiler sales	●	

	Head of R&D / R&D	●	
	Department manager / Parts		●
	Service engineer	●	
	Project & Mechanical engineer / Order execution	●	
	Educational Consultant / Human Resource	●	
	Department manager / Service		●
	General Manager /Engineering		●
	Department Manager / Parts		●
Total		**12**	**9**
	33 participants within the comparative case study		

Descriptive study 2.2

The support: A PSS conceptualisation framework and the PSS tool PEC were applied within a comparative case study with the two selected companies. PEC was used both to identify the case companies and to design the workshops.

The comparative case study used participant observation as a main method for data collection, and the action-based research approach was strongly manifested through this method. The prescriptive study was designed around a series of three development workshops, within which each of the workshops the support was implemented and facilitated with a single variable, the participants. All of the four PSS framework dimensions were integrated within the workshops: Offering Life Cycle; Value Proposition; User Activity Cycle; and the Ecosystem. The author therefore had the role as facilitator through a participatory design approach. The first two workshops were held individually at A: PrimeServ Frederikshavn; and at B: Alfa Laval Aalborg; and workshop C was conducted with both companies (A+B) participating in a co-development activity.

Analytical generalisation was used in evaluating the support. By video and audio recording the development workshops and following transcribing the material, allowed for coding the workshops to evaluate the effect the support tool had, using the new theoretical construct – PSS Concept Elements. For coding and identifying the PSS CE and their characteristics, a set of categories were developed, from which the measures could be evaluated, and guided therefore the analytical process of generalisation. For this a set of rules and a coding scheme were developed to serve as backbone during the analysis. The coding scheme had a total of 32 categories covering the five measures: i) Servitisation strategy; ii) Novelty; iii) Coverage of the four PSS dimensions; iv) Network efficacy; and v) Feasibility. The coding was unfortunately not based on investigator triangulation which would have further strengthened the results.

4.

Industrial research context

4. Industrial research context

This chapter elaborates on the empirical foundation that this research project is based on. The research object is the maritime industry, covering a set of ten suppliers. The chapter provides an overview of the industry, together with a description of the involved companies. The chapter acts as the backbone of any later mention of the companies and industry.

4.1 The Danish maritime industry

Today, 80-90 % of the world trade volume is transported around the globe by sea (*Danish Shipping Statistics* 2014; *UNCTAD (Review of maritime transport)* 2013). Furthermore, the world has an increased need for shipping as international trade has grown, with developing countries increasing contribution to the world economies[4] (*UNCTAD (Review of maritime transport)* 2013, 18). With the global focus on reducing toxic chemicals and greenhouse emissions and general use of non-renewable resources, shipping might see larger increases than other transport solutions because it has large environmental benefits over other methods (e.g. airfreight). Within this big picture, Denmark was responsible for more than 10% of the world trade measured in value, and 5 % of the world fleet[5] were controlled and “operated” directly by Danish shipowners (*Danish Shipping Statistics* 2014). Furthermore, the maritime industry was the biggest export industry in Denmark, with shipping shares of total Danish export of 20% in 2013 (*Danish Shipping Statistics* 2014, 15). Besides this, the industry employed approximately 100.000 people (*Danish Shipping Statistics* 2014, 18). (Table 15) The employment percentage indicates the importance of the industry to Denmark. The industry covers many different maritime companies and professions, such as manufacturing companies, service-oriented companies, consultancies, shipowners, shipping companies, shipyards, educational institutions, and many more. The situation has inspired the term ‘Blue Denmark’.

Table 15: Direct and indirect employment in the Danish Maritime Cluster (*Danish Shipping - key figures* 2014)

Direct and indirect employment in the Danish Maritime Cluster			
Industry	Direct	Indirect	Total
Shipping & maritime services	50 000	19 000	69 000
Shipbuilding etc.	1 000	2 000	3 000

4 Global growth increased 2.7% in 2013, whereof more than two-thirds of this was generated by emerging markets economies. (*Shipping market review DSF* 2014) p. 4
5 World fleet is here measured GT (1000) 56.383 / DWT (1000) 80.259. Compared to Japan 11 % GT (1000) 126.925/ DWT (1000) 187.313.

Equipment manufacturing	23 000	10 000	33 000
Offshore exploitation	2 000	2 500	4 500
Fishing	4 000	1 500	5 500
Total	*80 000*	*35 000*	*115 000*
The Danish maritime Cluster's share of the total Danish employment (%)	*2.9*	*1.3*	*4.2*

4.1.1 The change within the Danish maritime industry

The Danish maritime industry has a long history of strong global competitiveness, and Denmark has been known as a high quality and technically advanced shipbuilding nation for decades. This is in part due to close collaboration between shipowners and shipyards; e.g. the collaboration between former OSS (Odense Staal Skibsværft) shipyard at Lindø and the large 'conglomerate' A.P. Møller Mærsk Group. This type of collaboration caused that shipowners in Denmark historically have placed large proportions of the production of fleets nationally. Eugen Mærsk, with the technical number L210 and one of a seven-ship series, was the biggest container ship in the world at the time, with the capacity of 11,000 TEU container units. It was also the last ship built in Denmark, thereby ending many decades of Danish shipbuilding activities in 2011, leaving behind only repair shipyards and small-scale specialised ship building. Many similar changes were found throughout Europe due to outsourcing of shipbuilding to the East: First to Japan, then to South Korea, and currently to China. Consequently, the European share of new builds has dropped in the last few years to 6 % in 2013 (*Danish Branch Association annual report* 2013, 26) from 20% (*Danish Branch Association annual report* 2011, 19)(Figure 16). The Eastern competitiveness mainly arises from low-wage labour at the shipyards, increasing industrialisation, and national government subsidies, which lowers product cost, time to market, and increases product quality. Despite the shift of the shipbuilding activities to the East, European shipowners still control the shipment of 20% of the world cargo tonnage (*Danish Shipping Statistics* 2014) p.6. Furthermore, the repercussions caused by the global financial crisis of 2008 included large order book cancellations. In 2012, the level dropped to approximately 50% below the 2008 peak, leaving all suppliers with large purchase cancellations and a completely changed market. To exemplify such a radical disruption in the market, it is interesting to note that a large container ship accounts for up to 2,500 suppliers. Despite the cancelations, the crisis led to an oversupply of new builds, where the world fleet capacity in 2011 exceeded by 20% the cargo volume[6]. The world fleet had actually doubled in size from 2001 to 2013 and this caused low and volatile freight rates (*UNCTAD (Review of maritime transport)* 2013) p. 14.

[6] The world fleet increased by 44% from 2008 to 2013 despite the cancelation (*Shipping market review DSF* 2014) p. 8

This together with high fuel cost, which accounts for more than half of the daily operating cost of a ship, made the earnings for the carriers reduced and close to (and even below) operating cost (UNCTAD p. 26). In addition, shipowners were challenged by the drop in the value of the ships due to overcapacity and thereby a reduction of the shipowners' assets. This reduced the second-hand price for ships to remarkably low levels of freight rates, together with high scrapping prices resulted in increased demolition activities (*Shipping market review DSF* 2014). The premature scrapping of vessels made the world fleet young and the average operating life of vessels shorter, and even lower than the technically expected operating life (*Shipping market review DSF* 2014).

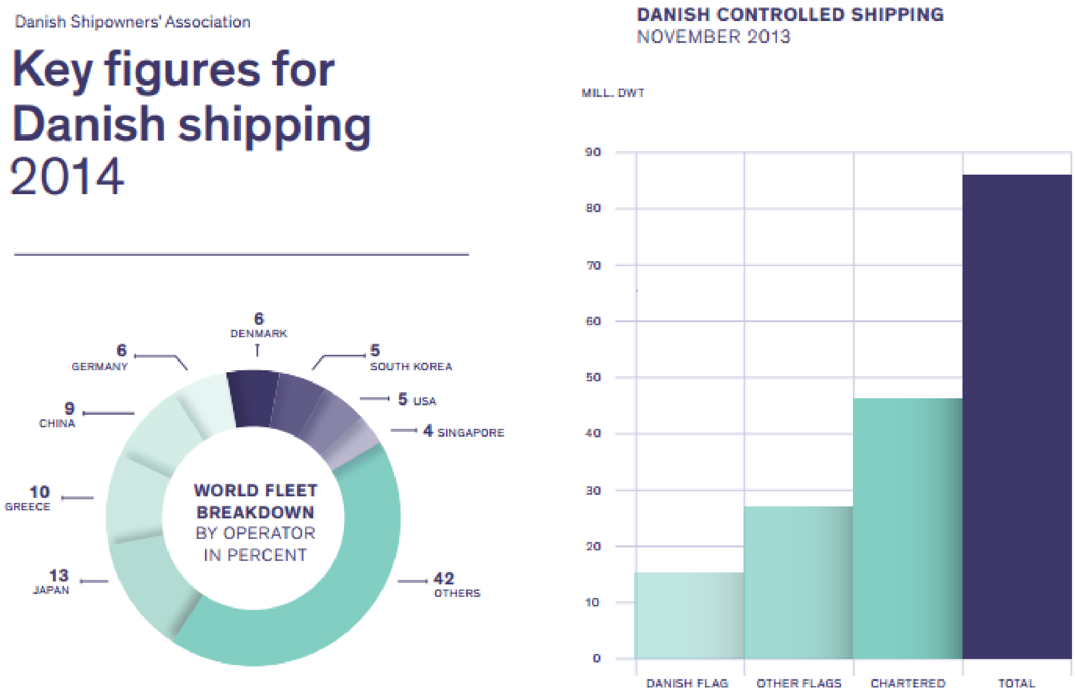


Figure 16: Key figures for Danish shipping. Left; percentage of world fleet, right; percentage of Danish controlled ships

The stalling of the global maritime market gave rise to a maritime industry landscape with the largest world fleet in history[7]. The market for after-sales service to maintain fleets' efficiency through regular maintenance and e.g. retrofit-solutions increased by:

i. a shift to slow steaming to reduce fuel cost (*Shipping market review DSF* 2014), which in turn required adjustments of the propulsion system on-board the ship;

[7] The size of the world merchant fleet consisted in 2012 of 79.471 ships. Reference (Equasis statistic – 2012 merchant fleet)

ii. high industry regulations, e.g. with the International Maritime Organisation's Environmental Protection Committee agreement on stricter requirements for ships, e.g. emissions of NOx, new standards for sulphur in bunker fuel and levels of contaminants and microbes within ballast water; and
iii. through a strong focus on solutions to meet specific customer needs in connection with the conversion of ships to include new functionality, by retrofitting the whole ship or parts hereof.

Such global market displacements within the shipbuilding industry affected directly the influencers in the industry. The bargaining position had traditionally been at the shipyard due to high ship building activity, caused by the high demand for new-builds, which affected the choice of suppliers for the ship. Cost and delivery time were prioritised higher than quality and service levels with the philosophy 'most ship for lowest price'. With the market change, the prime decision taker in a new-build order shifted from the ship builder to reside at the shipowner. The added barging power in the contracting phase of a ship-build to the shipowner made it possible for the shipowner to favour decisions with a focus on the long-term cost of the ship, thereby bringing in possibilities to choose PSS solutions. These market changes together with the continuing market globalisation demanded an increased focus from the Danish maritime suppliers to broaden their customer focus towards the shipowners and expand their product/service portfolio accordingly.

Summarising the findings from the descriptive explorative study is listed here below:

4.1.2 The challenges the change brought

- The global reach of the industry and, thereby, its market of cultural variety have resulted in differences in the perceived value of each service (and the need therefore) by customers from different countries.

- The transport industry, as an international trade system, requires a globally-reaching service network. In particular, the maritime industry requires: i) long "on seas" periods; ii) irregular shipping routes; iii) an efficient service when the ship is in port; and not to mention iv) an understanding of the differences in the flag state rules within each country. All these requirements make it difficult to meet the service needs of the shipowner.

- In the PSS solutions, where ownership moves from the customer to the suppliers, causes resistance (due to mental mindsets). The legal restrictions placed on the main capital asset (the ship), which is not stationary, also causes difficulties for the 'regular lease systems' and insurance, and financial support solutions.

- The high-value goods, e.g. retrofit solutions, are expensive. This means that insights and data on Return of Investments (ROI) are especially important as is a need for increased collaboration with financial partners, where the above legal issues also apply.
- Ship brokering, where the ship 'circulates' between different shipowners, combined with a complex shipowner organisation and a non-transparent decision-making structure and 'customer, buyer and user' constellation makes it even harder to: i) capture and match the myriad user needs; ii) be proactive; and maybe most importantly iii) implement an understanding of the PSS benefits.
- Despite its high quality products, experience, and agility towards customer demands, the industry, in general, lacks a formalised development processes. A good example of a formalised development process is the classic product development stage-gate model. This development model was project-based, and furthermore, was found to occur as an integrated part of the production. Since the production at the companies was often outsourced to lower wage countries, the knowledge loop from production would soon disappear. These observations increase the need for a formalised process.
- In cases where companies have licensees (e.g. for product upgrades on spare parts or for small retrofit products), upgrade information was given to both licensees and sold to customers. Here, the suppliers competed against their own "knowledge" and lost (gave away) market shares to keep a good relationship with their licensees.
- Finally, the Product Life Management and Customer Relationship Management systems were not broadly implemented within the industry, which jeopardised customer relations and product feedback.
- Keeping up-to-date with the strongly regulated industry concerning safety and environmental issues was a challenge for the companies, no less difficult with the changing compliance levels from country to country. This is why collaboration with lobby organisations and branch organisations became even more important.

4.2 Key characteristics of the PROTEUS companies

The Innovation consortium PROTEUS had 10 participating companies during the research project. This section elaborates on the two single case studies, used for the comparative case study in DS2. Table 16 gives an overview of all the companies, their size, location, business, and core offerings. Refer to appendix B for a detailed description of the case companies.

Table 16: Overview of PROTEUS companies. Companies marked * were the companies selected for the comparative case study.

	Size	Type of Business	Core offering
YIT Marine (Caverion)	24.000	Electronic company / Engineering design	Cabling and control systems. El-technical and monitoring solutions
Hempel	5000+	Chemical	Paint and coating advisory
***Alfa Laval Aalborg**	4000	Engineering design	Boilers and heat exchangers and water treatment systems
***MAN PrimeServ Frederikshavn**	300	Engineering design	Aftersales for four-stroke engines, propulsion packages
Emerson MTM	640	Engineering design	Marine Tank Management: valve-remote control systems, radar solutions, and tank gauging and monitoring.
Novenco Fire Fighting	35	Engineering design	Fire Fighting Equipment, water mist nozzle systems.
PresVac	50-99	Engineering design	High-velocity pressure-vacuum valves, deep-well cargo pumps and venting systems
Lloyd's Register ODS	65	Consultancy and engineering	Consultancy in engineering dynamics: noise and vibration control, rotating machinery and structures.
NoreqActa	125	Engineering design	On-board ship Cranes and life-saving equipment
Klinger Danmark	20-48	Engineering design	Valves and gaskets

Alfa Laval Aalborg and MAN PrimeServ Frederikshavn

The companies Alfa Laval Aalborg and MAN PrimeServ Frederikshavn formed the basis of the in-depth case study for the testing of the empirically created framework for network-based PSS development in this thesis. These two companies are therefore introduced in full in sections 4.6 and 4.7, respectively.

4.3 Industry view on PSS & motivation

The motivations for the companies were varying. With the increased competitiveness from Asian countries, and the closure of the new-built industry in Denmark, all companies had a main motivator to strengthen their competitiveness globally. The following summarises the motivation from the companies (Mougaard et al. 2013):

- Strengthen competitive edge
- Enhance value creation for the customer
- Knowledge sharing across companies
- Network opportunities globally
- Structured and defined service development activity
- Increased utilisation of existing competencies and expanding of these to match new business strategies.

Besides the key motivations, the explorative study indicated that the industry had already established an understanding of the possibilities of after-sales services: "*The big difference is not to focus on service as another product but to implement a new selling approach, which includes technical service as a part of the solutions. In other words, to sell the value we create for our customer´s business and not only talk about product, or hours spent ..." [PROTEUS Company].* This indicated the companies' awareness that a PSS approach requires a new mindset of the sales people and in general within the whole company. Despite this awareness, it was still observed that the companies were lacking insights into the transitioning process, expanding the service-oriented offerings, and increasing the market. "*... we have 20.000 of our products on the market but we only provide service to approximately 25% of these. This is where PROTEUS should help us ..." [PROTEUS company].* It was found that in general, after-sales activities were operating at a cost rather than a profit to the companies, where the services were not sold effectively but rather given away to increase product sales. This also was expressed: "... *The whole after-sales department could be an independent business unit ..." [PROTEUS Company].* The above quotes illustrate that the PSS oriented business needs focus on new solutions for the customers (PSS solutions), new development approaches, processes within the company (PSS development), and service-oriented business strategies, where coordination of PSS development and operation can be facilitated (PSS approaches).

Across all the companies, interest was stated to be aimed at "knowledge sharing" and "network opportunities globally". In general, collaboration between the industry stakeholders was seen as a core element in the recognised need for industry change.

4.4 The industry network

This section will elaborate on the Danish maritime industry network and the positioning of the PROTEUS companies within this. The analysis was part of the explorative analysis in the Descriptive phase of the research project. The main focus was a simple stakeholder network description to highlight the vital industry stakeholders, their roles, relations, deliverables, and prime collaboration. Refer to Figure 17.

Figure 17: Maritime stakeholder network (author's own graphic)

Note: *The following sections refer to the letters in Figure 17 to describe the various observations made. Notations are made in parentheses, e.g. '(A)'*

4.4.1 Multiple roles within the network

The PROTEUS companies had multiple roles, despite being providers of manufactured goods. They were affiliated with multiple stakeholder groups and roles. Refer to Figure 17 – letter (S) corresponds to supplier and marks the different roles and thereby the participation within different stakeholder groups.

Where the suppliers:

- Delivered equipment and services to the shipyard.
- Delivered equipment and services to the shipowner.
- Acted as sub-supplier to a supplier.
- Was a financial partner in long-term contracts with the shipowner.
- Was a development partner to another supplier.
- Acted as academy educating their customer.
- Was a service-network partner to another equipment supplier.
- Acted as a technical department advising the customer in maintenance.

4.4.2 Changing position within the network

The different roles mentioned above clearly indicate that the position of the suppliers within the industry network had changed from a classic sequential value chain towards a value system. Value was created across different stakeholder groups spanning multiple life cycle time domains, moving away from a linear value creation.

The relationship between supplier and sub-supplier, marked as (A) in Figure 17, was seen as increasing in importance for being able to deliver high quality products without delay and at a minimum cost. Strategic supplier/customer-relationships were found, though many suppliers were struggling to establish the right sub-supplier contract, to favour both new-sales and after-sales departments' needs. Large parts of production were outsourced to lower wage countries, keeping only crucial production nationally due to IP or quality testing. Licensees were also used by a few of the suppliers. As mentioned earlier, this can be of risk in after-market competitiveness, and new product development as an important knowledge feedback loop weakens. A tendency in the manufacturing companies was acquisitions, where many suppliers consisted of sub brands. This lead to sales of better integrated systems but caused organisational challenges. Also, suppliers mostly within commodity products would act as sales-houses developing and producing only limited amounts in-house. The supplier's ability to perform well in the after-sales period was highly dependent on their ability to deliver spare parts and to run any warranty issues. The suppliers that offered services, such as repairs or reconditioning of a system, depended on having spare parts in stock or being able to reorder without delay. This was intensified when the suppliers were in a closer relationship with the customers, having full responsibility for the maintenance activities. This development moved the suppliers closer to the customer and towards a business partnership with the shipowner (F).

4.4.3 Knowledge sharing and collaboration

The maritime branch organisation was seen as highly important as the industry is globalised, making it hard to overview all regulations and legislation. The organisation acted as a direct mediator of world-wide market trends and continuously influenced emerging regulations in favour of the Danish suppliers' capabilities, with focus on lifting the quality of the world fleet (B). Regional interest organisations were also seen emerging through governmental support to strengthen the utilisation of the large maritime competences in different areas; e.g. MARCOD Maritime Centre for Operations, EMUC European Maritime Development Centre, and DKMK Danish Maritime Cluster[8]. The relations between the suppliers were observed taking place via collaboration networks, e.g. with focus on Product development (C). The most common relationship between the suppliers was a regular customer/supplier relationship (A), but collaborations on retrofit products were becoming increasingly common. Here multiple suppliers collaborated on developing state-of-the-art products that met the latest or future regulations. Also, operations-oriented networks (C), such as the Maritime Network in Frederikshavn, were an example of how multiple suppliers were collaborating in order to offer holistic after-sales solutions for their customers in a one-stop-shop format as they acted as a strategic marketing network.

4.4.4 Changed value propositions

With focus on fleet efficiency, the typically long operational periods of ships (up to 30 years) gave rise to preventive maintenance being offered by many of the suppliers (F). This necessitated a shift in focus for the suppliers, from unit cost (cost of the goods produced) to life cycle cost (connected to offering long-term maintenance), which in turn demanded for a new focus by the supplier on the management of own assets. Also in this preventive approach, openness from the customer was needed to give access to the right level of data. Offering flat-rate service contracts increased the suppliers´ need for a stable relation with their banks to

[8] A follow up for this EU supported maritime cluster was established and began September 2014 ("Danmarks Maritime Klynge "DKMK"). In the second period of the project, focus was moved from educational institutions to educating the already in-market employees, with specific focus on industrial manufactures.

ensure liquidity and freedom to operate (E). Some of the larger companies were offering financial packages in partnerships with financial institutions. These offerings seek to support the shipowner, using a Total Cost of Ownership approach (F), supporting the customer in long-term planning and with focus on short-term pay-back time for a maintenance program; e.g. five years or less. Short-pay-back time was also needed when regulations from legislative institutions such as SOLAS and IMO resulted in new requirements and need for expensive retrofitting solutions to stay in compliance. This increased the relationship between the shipowner and the financial institutions (G). The maritime industry is characterised by its large focus on approval of components (slowing down New Product Development cycles), which is required to insure the vessel. The vessel's compliance is stated through the "vetting" process where the statutory regulation entity (i.e. the classification society) inspects the ship, system, or single components. The shipowner needs to insure (D) the vessel so as to meet future issues with responsibility (claims) in connection to securing the cargo and delivering on time.

4.4.5 Sharing risk - contractual challenges

The change in value propositions and the increasing focus on service agreements, or the more complex performance agreements, created an element of added risk for the supply company. This was seen as a challenge. These agreements often introduced a complex myriad of new contractual responsibilities, shared among multiple companies, covering many relations between customer, suppliers, and suppliers' suppliers (A), (B), (D). The industry experienced an increased focus on legal terms within these contracts. In general, the industry was faced with the classical challenge of changed ownership or responsibility (e.g. in outsourcing all maintenance). Suppliers feared that the crew/shipowner would not operate and carry out daily maintenance at a satisfying level. In addition, they doubted the transparency of the service agreements and questioned all added and charged services. Furthermore, risks were occurring in the effort to be prime mover on new product development to meet new future regulations. The risk were on both supplier and shipowner: i) if the shipowner would not in advance plan or invest in a retrofit schedule, the shipowner would risk down-time; and ii) the supplier would lose their position as prime mover in pushing for a specific regulation as well as risk that the retrofits would not be implemented after all or result in a longer market launch than expected, causing major loses in the company.

4.4.6 Establishing global presence

Being at the right place at the right time is crucial for the success of any service business. In the maritime industry, when a breakdown occurs on a ship time is of the essence and product/service prices become less important than the time it takes to fix the problem. Large companies were often seen to have self-owned service stations at key geographical locations. This requires a substantial investment to set up but also retains the profit within the company. The smaller companies would send out a service squad or collaborate with external service networks. Here it was observed that the suppliers were training each other's technicians to expand their global presence. Many suppliers offered education and training for the shipowner's crew and/or technical department, thereby furnishing the on-board technicians with the tools to better support their products and thereby changing the relationship (F) with the shipowner. The mapping at Figure 19 illustrates all the companies' global presence. Top 12 PROTEUS supplier locations were located in ports covering 15% the world cargo volume, compared to the top ten busiest ports, which covered 30% of the world cargo volume.

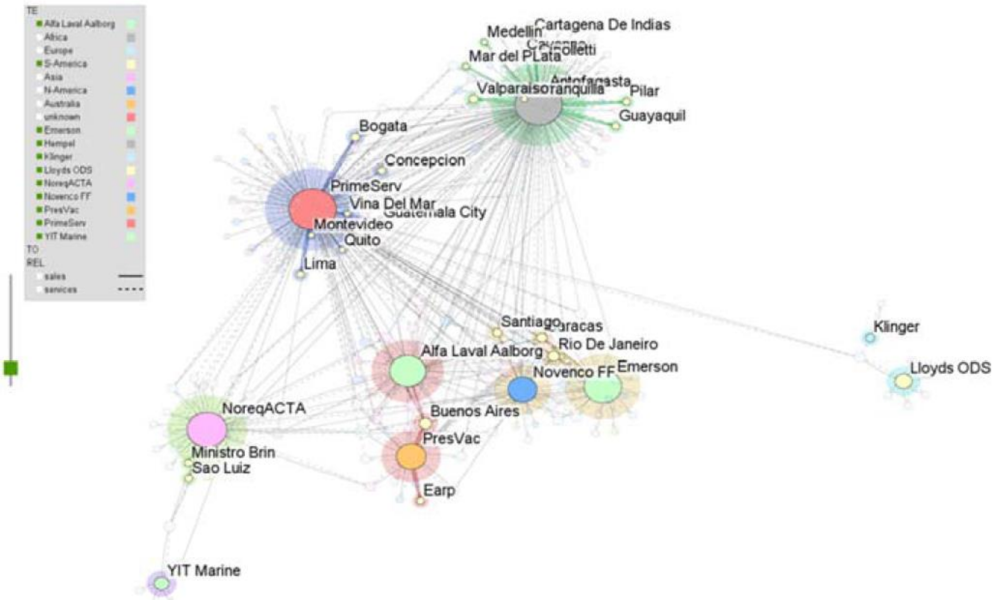


Figure 18: Network illustration of service providers according to geographic location by (Storga et al. 2013)

Another way to represent the distribution network (service network) was illustrated by Storga et al. (2013) using a tool called Organic Viz (Figure 18), Storga argues that this approach - the approach of visual analysis - is an essential method in engineering system design, to manage and exploit the large data sets that is available today by new technologies, and bring these into the activity of engineering. "*... the general science of networks and its various multi- and transdisciplinary applications such as visual analysis have significant relevance for engineering systems design research ...*". The figure illustrates the network of companies based on the shared geographical locations. This made it possible to identifying affinities where specific services were offered at the same location, to find opportunities for collaboration.

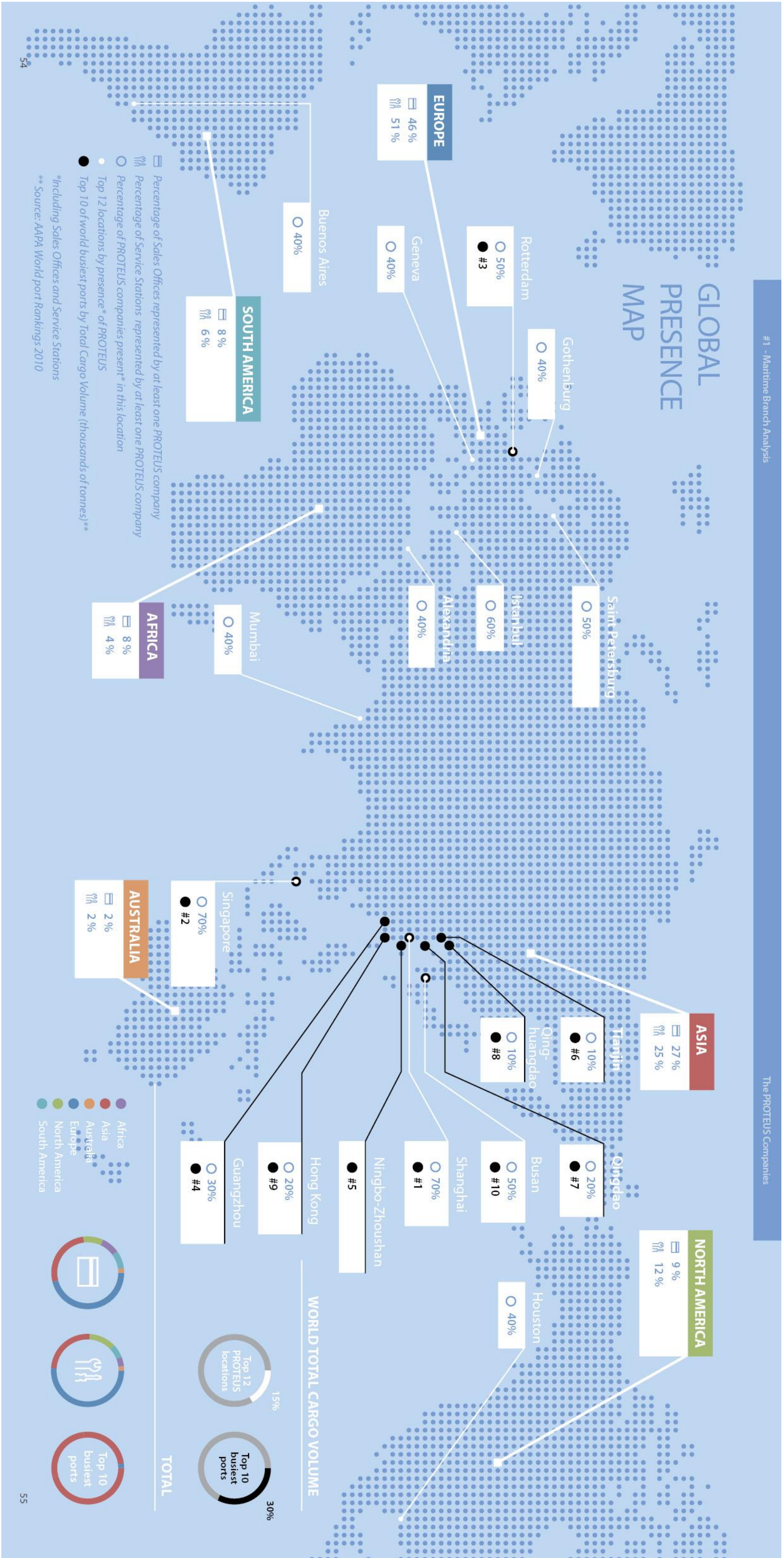


Figure 19: PROTEUS companies and their global presence (author's own graphic)

4.5 The case companies – a comparative case study

See the in-depth description of the relation between the two case companies in chapter 7 section 7.1.2. To summarise the two case companies were chosen due to their:

- Company profile – with affinity in products and service offerings.
- History in collaborating with each other.
- They shared future visions – in increasing their service portfolio.
- Shared interest in a systematic way to develop and maintain service solutions.
- They were independently striving towards an increased academy in house.
- They had collaborated on retrofit solutions previously.
- They were located geographically close.
- They were in a supplier-customer relationship
- Both companies could sell service to one another products.

4.6 Case company 1: MAN PrimeServ Frederikshavn

MAN PrimeServ is the brand name of the aftersales business unit of MAN Diesel & Turbo, wherein they as an OEM provide service for large marine propulsion systems covering both two-stroke and four-stroke engines with services on-site, at seas, and in ports all over the world. Their large service network which spans 90 PrimeServ locations (MAN rep. 2010)., and employs approximately 2800 (Mougaard et al. 2013). MAN Diesel & Turbo were world known for their high quality products and as a market leader of new technology development for marine propulsion systems, particularly with their focus on green developments reducing the environmental impact of the ships. As an engine has high running hours (e.g. 8000 hours per year) and fuel cost, which accounts easily for 50 % of the daily operating cost of a ship, the engine are of high importance in efficiency matters. As mentioned earlier, the lubricating oil system, main engine, and auxiliary engine is within the top four biggest life cycle cost areas for a ship. Furthermore, the criticality of the propulsion system to the operation of the ship makes it, not surprisingly, of high importance for the shipowner. This is why the after-sales market for ship propulsion system is large.

The MAN PrimeServ brand was established in 2006 to reinforce the after-sales activities: "... *The new brand represents our commitment to high-quality diesel engine service and the ability to supply customers with original replacement parts within 24 hours ...*" (Annual report 2006). Six years after this statement, they had grown their business unit remarkably and changed their aim to strive towards becoming a market leader on marine propulsion system services: "*We aim to be the leading service company and a reliable service solutions partner to our customers ...*" (*MAN*

PrimeServ annual report 2012). They described their service as: "*Our customers benefit from our service solutions, which can be implemented at any time in order to increase service life, improve availability, reduce emissions or simply deliver the right parts and labour quickly …*" (*MAN PrimeServ annual report* 2012). The wording used in describing the after-sales offerings with six years difference indicates a big change in their communication and scale of the offerings within the company during this short period; from spare part and delivery time to increased product life and availability (service solutions).

The history of MAN Diesel & Turbo Frederikshavn dates back to 1883, with the foundry and machine shop called *Frederikshavn Jernstoeberi og Maskinvaerksted,* which was started by the Houmoeller brothers. They had their breakthrough with the combustion engine, a paraffin hut-bulb engine which was marketed under the name DAN. Burmeister & Wain (B&W) shipyard in Copenhagen manufactured this engine up to 1896, when the engines were discarded in favour of Rudolf Diesel's invention of the Diesel engine at the Maschinenfabrik Augsburg Nürnberg (MAN). In 1902 the company launched their first variable pitch propeller, the so-called controllable pitch propeller (CPP) and was later in 1938 acquisitioned by B&W. In 1980, B&W Diesel A/S was established and the shares sold to the MAN Group.

In late 1990, Frederikshavn was hit with a big unemployment wave due to the closure of the shipyard Danyard, which resulted in a layoff of more than 2000 employees. Later in 2010, MAN Diesel & Turbo in Frederikshavn closed down the last production of four-stroke engines, dismissing approximately 500 people. In 2014, the city with their strategic location at the seaside with heavy sea traffic, the *Port of Frederikshavn*, aimed at becoming the centre of a big maritime cluster, with focus on repair and maintenance facilities with larger overhaul of ships, thereby recreating jobs in the Frederikshavn area.

4.6.1 The business

MAN Diesel & Turbo employees 12.500 people, split in four strategic business units, (1) Engine and marine systems, (2) Turbomachinery, (3) Power plants, and (4) Aftersales. At the MAN Diesel & Turbo in Frederikshavn, they hold activities within two of the business units, *Aftersales* and *Engine and Marine Systems*. Where MAN PrimeServ Frederikshavn employees 500 people, and are one out of out of six headquarters within the aftersales business unit, it is furthermore a "competence service centre" for four-stroke propulsion engines but also offers services for propellers and control systems. The business unit *Engine and Marine Systems* offers complete aft ship solutions, with propellers and automation systems for ships, wherein they have a large R&D department plus the remaining part of the manufacturing.

MAN Diesel & Turbo are market leaders in the area of diesel and gas engines, used in medium and low speed applications on board-ships and for stationary power plants, with a market share of more than 80%. Furthermore, they are also among the top three market leaders in medium-speed four-stroke engines and exhaust turbochargers. They have one of the world's largest install bases of engines, claiming that more than half of the world fleet has a MAN Engine on-board, which accounts for more than 48.000 Vessels[9]. They have yearly revenues of 3.8 billion EUR, with 439 billion operating profit. For their two-stroke engine, they have outsourced almost all of the production to licensees counting up to 35 companies globally, whereof 20 of these are Chinese firms. The four-stroke engines are manufactured in-house on sites mainly in Germany, France, and India. Their business models are purely business-to-business, where the main customers are: i) shipyards and shipowners by selling the propulsion systems and services; and ii) the licensees. Their main marine markets are cruise & ferry, merchant, navy, and offshore.

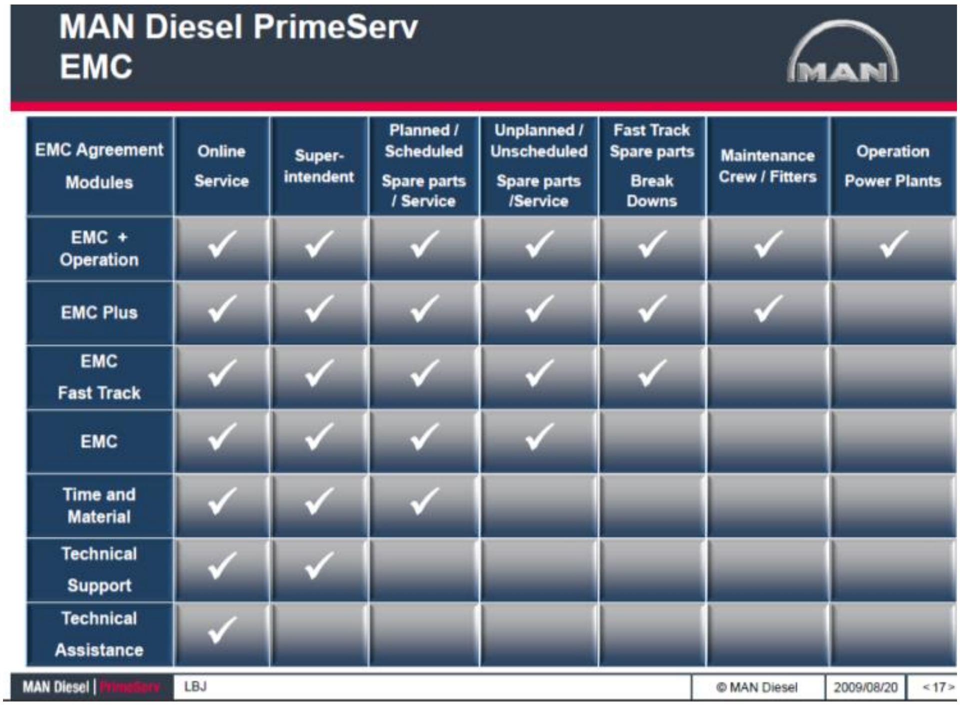
4.6.2 Product and service portfolio

MAN PrimeServ had the most advanced service offerings within PROTEUS. They have a comprehensive portfolio of services, covering everything from add-on services to highly integrated product/service offerings. From spare part agreements, financial services to very complex retrofit solutions, and management of maintenance activities. A list of the most PSS oriented (and within the consortium unique) offerings:

- *Financial services*: Called Trident, facilitates customers' investments in retrofit solutions. The focus here is on solutions with a pay-back period of less than two years.
- *Maintenance management*: EMC, Engine Management Concept, PrimeServ has the responsibility for optimising engine life cycle cost through maintenance and operating activities of the engine for a fixed monthly fee through a dedicated key account manager (superintendent). These contractual terms are choices of the customer. Refer to Figure 20. Here a set of parameters can be selected and configured matching the needs of the customer.
- *Academy:* Training of customers' service technicians. With focus on different service engineer profiles, the customer´s crew or technical department gets an increased competence level.

[9] They have no annual reports including their install base of their products; neither do they report on market shares etc.

- *Retrofit:* In a close partnership with the shipowner retrofit solutions are developed and vessels are converted to hold new and better functions and be in compliance. For example, with the new TIER III IMO standard valid from 2016, they have three years in advance developed and marketed retrofit solutions for their two-stroke engines.



EMC Agreement Modules	Online Service	Super-intendent	Planned / Scheduled Spare parts / Service	Unplanned / Unscheduled Spare parts /Service	Fast Track Spare parts Break Downs	Maintenance Crew / Fitters	Operation Power Plants
EMC + Operation	✓	✓	✓	✓	✓	✓	✓
EMC Plus	✓	✓	✓	✓	✓	✓	
EMC Fast Track	✓	✓	✓	✓	✓		
EMC	✓	✓	✓	✓			
Time and Material	✓	✓	✓				
Technical Support	✓	✓					
Technical Assistance	✓						

Figure 20: EMC Agreement module

MAN PrimeServ's EMC contracts (see Figure 20) had few, but large contracts, covering entire fleets. The contracts were sold mainly to liner vessels (with fixed routes), where forecasts could be made on running hours and planned maintenance thereafter. A contract obtained in 2013 was seen as a renewed interest in the EMC contracts. They believed this was caused by their increased collaboration between the global PrimeServ locations. This was exemplified by a close collaboration between PrimeServ Copenhagen and Hamburg. PrimeServ Copenhagen focused on electronically controlled ME-B engines, and experience with condition-based maintenance, while PrimeServ Hamburg focused their know-how and workshop facilities on refurbishment. "*This close relationship means that we can pool common resources and exchange knowledge, and are able to offer customers a considerably higher level of service than individual hubs would have been able to alone*"[10]. The expansion from 2006 with 40 PrimeServ hubs to 2012 with 90 gives an increased challenge in across-site collaboration and optimized use of site facilities and in general knowledge sharing.

[10] Press release details: Engines & Marine Systems – PrimeServ: 2013-05-06 MAN PrimeServ Signs Notable Maintenance Agreement with Frominent German Shipping Line

Academies became a main focus area in 2006 where they opened. At the time, their largest academy was at their Augsburg site. They aimed to strengthen their internal service capability level through an approach that they termed the "international service engineer." At the same time, they strategically aimed at exploiting the large knowledge built within the company, offering training courses to also strengthen their customers' capabilities to operate and service their products. *"Knowledge as a competitive edge*" (*MAN AG annual report* 2006, 76) was their strategic approach to competitiveness. Later in 2011, they had their opening of a large academy in Frederikshavn, with training in complete propulsion systems, and in addition to these standard courses a specific focus was on four-stroke GenSets (small bore). The academies geographic locations mirrored the previous "development and production" sites of the products. Furthermore, academies were seen as a potential source of feedback for product optimisation and new design though not formalized yet (Academy manager Frederikshavn).

The focus on retrofits to meet future regulations were high, "*As an OEM we set global technology standards, through ongoing improvements to our technology and ever-greater environmental commitment . . .*" (*MAN PrimeServ annual report* 2012, 12). They launched in 2012 a new sub area within their PrimeServ business unit called "PrimeServ green." There they packaged both products and services to obtain certain goals in terms of optimized efficiency, life extending packages, or focus on compliance issues.

4.6.3 Development activities

The development activities within MAN Diesel & Turbo account for 252 million EUR in 2008, equivalent to 6.7% of the companies turnover, which makes the company top ranked among Europe's high-tech companies. The development of two-stroke engines occurs in Copenhagen, and the development and production of four-stroke engines is in Augsburg, Germany. The development approach was strongly project-based, where collaboration with shipowners was vital for the development and later market launch of a new engine or a retrofit solution; i.e. conversion of an engine, to be capable of conducting a test period verifying for example a new engine performances and system stability. MAN Diesel & Turbo had a high level of research projects (e.g. Green Ship of the Future, Hercules B, Clean Ship Gas-Pax and Bio Clean), where collaboration between suppliers, universities, and shipowners took place. Wherein the development between suppliers was highly "integrated product development".

The development organisation had little alignment between the two product-based business units (Engine & Marine Systems and Turbomachinery) and their after-sales business unit (PrimeServ), which caused a gap between after-sales and new-sales development. This also extended to their sales organisation as new sales and after-sales were two separate function areas. Between the two major product groups of two-stroke and four-stroke propulsion systems, the feedback loops from e.g. two-stroke engine R&D (Copenhagen) to MAN PrimeServ "Competence centre" of four-stroke engines (located in Frederikshavn), were particularly sparse, thus omitting key knowledge exchange regarding after-sales offerings. This also applied the other way around, where after-sales development had upgrades and retrofits and conversions that could be sold as an integrated part of new-sales. At the time of the research project (2010), regular knowledge sharing was taking place between the different after-sales units; e.g. quarterly meetings were arranged between PrimeServ locations.

Structured "new-service development" processes were not implemented at the company, a process was implemented for Retrofit projects (project-based development) as Figure 21 illustrates. Here, a process diagram from inquiry to design and production and finally installation and commissioning is detailed.

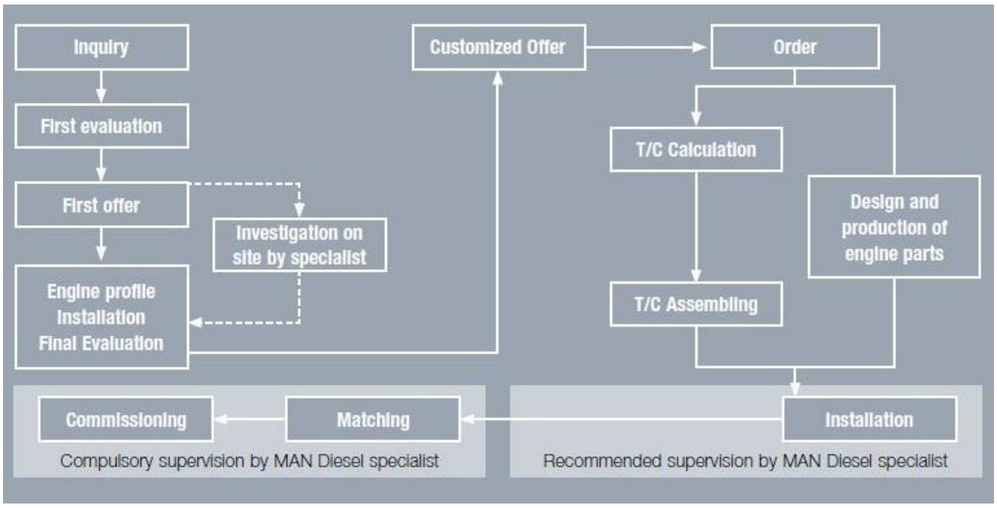


Figure 21: Project-based development model

During the research project, many organisational changes took place. Just before the research project started, an in-depth analysis of the service processes were mapped by an external consultancy firm, with the focus of 'Lean' in the service processes and particularly with focus on the workshop facilities (it did not cover any processes for new service development). The service development at Frederikshavn were at the time divided between two departments, "Retrofit Projects" and "Sales & Projects," where the former focused on more advanced conversions and retrofit developments and the latter on standard service projects at the port. At the end of the project, these two departments were merged.

4.6.4 Motivation & challenges

PrimeServ Frederikshavn, with their dedicated after-sales business unit, had a large product/service portfolio, with a high level of new service development, where new retrofit products and services were developed frequently. With the continuation of increased fuel prices and stricter environmental legislation, together with a focus on increased operating efficiency, the after-sales market had possibilities for increased expansion. Top management within MAN Diesel & Turbo had committed to after-sales as a being a business area with a possibility for increase in sale. The company had challenges to sell its after-sales offerings, partly because new-sales of products did not systematically include service contracts. For this reason the potential opportunity to maintain the relationship with the customer, after the traditional warranty period had expired, was not realised. Therefore MAN PrimeServ needed to proactively contact all customers with their after-sales service offers. The sales department within PrimeServ Frederikshavn was divided into i) spare part sales and technical service ii) retrofit iii) overhauls iv) service engineers with on-site service inspections and repair and v) EMC. Within each function unit, there were no service portfolios with a strategic overview of the services within PrimeServ. Furthermore, despite the information being available for each customer, no automatic service configuration was made based on engine and vessel type. PrimeServ Frederikshavn increased their service forecast activities and business intelligence in terms of after-sales possibilities. They had, for example, service analysts focused on internal data on customer portfolios (similar to CRM holding information on service logs and product installs) and external databases like Fairplay with brokering, ship routes, and docking information in order to increase proactive service sales at PrimeServ Frederikshavn.

In general, the company's motivation for participating in PROTEUS was mostly focused on improved exploration of service solutions and the development processes for these. Discussion and experience exchange regarding customer service provisions and customer satisfaction were of high interest for MAN PrimeServ Frederikshavn.

4.7 Case company 2: Alfa Laval Aalborg

Alfa Laval Aalborg´s is the marine after-sales headquarters department within Alfa Laval, located in the city of Aalborg in Denmark. Alfa Laval Aalborg (former Aalborg Industries) is known for their large portfolio of leading technologies for heat transfer, fluid handling, and separation on board ships, offshore "floating production systems," and also land-based applications. On ships, the products' function is of high importance to the propulsion system as they handle engine cooling, production of freshwater, and treatment of fuel and lube oils, together with sludge and oily water. The company's a vision statement (2012) claimed: "*... we* *provide energy and safety solutions maximizing our customers' competitiveness and generate new technologies that benefit the environment ..." (Presentation from shared workshop).*

The department has been offering service since 1960 and opened its first subsidiaries abroad in 1978 in Singapore and the Netherlands and today has a global presence covering 99 service centres, which have grown 50% the last five years. Within the aftermarket, they have a strong position because Alfa Laval has a large install base, including 35,000 marine boilers and heat recovery units. The company claims that more than 50% of the world's new-builds are provided Alfa Laval's marine boilers. After Alfa Laval acquisitioned Aalborg Industries in 2011, the marine division increased with their 2500 employees. Aalborg Industries thereafter became a sub-division of the Marine and Diesel Division (which has 4000 employees) and is the main organisation behind their maritime market. Alfa Laval saw the aftermarket business as a key part of their operations: "*This business generates favourable profitability and involves frequent customer contact, which also provides added support for new sales. It is also less sensitive to economic trends. From a customer perspective, having quick access to service and spare parts when necessary is crucial."* They expressed that they would have aftermarket as high-priority area in the future (*Alfa Laval annual report* 2011).

The history of Alfa Laval Aalborg dates back to 1912, with the establishment of Aalborg shipyard in Denmark with the name "P.Ph. Stuhrs Maskin- og Skibsbyggeri." In 1919, their first marine boiler was designed, a riveted Scotch type boiler, which was built at the shipyard for their own new-builds. In the 1950s, they increased their international sales of boilers. In 1987, the shipyard closed, and the year after they acquired "Dansk Fyrings Teknik" with oil-and gas fired burner products and expertise. Ever since, they have made several acquisitions of smaller companies, (competitors and complimentary) and hold today a myriad of sub brands that cover total system offerings to handle heat and water treatment connected to ship operation.

4.7.1 The Business

Alfa Laval employees 15,000 people within their four different divisions, where three of these are market adapted sales organisations: 1) Equipment; 2) Process technology; 3) Marine & Diesel; and 4) Operations division, which were production-related procurement, manufacturing and distribution. Alfa Laval has today manufacturing at 37 different locations, and more than 50% of their labour in connection to production is placed in low-wage countries.

Direct sales to end-users are limited within the Alfa Laval group, but within the Division of Marine & Diesel sales are also directly to the end-user. The customers are mainly manufactures of marine engines (e.g. MAN Diesel & Turbo), but they also sell directly to shipyards and shipowners. Within each of the three sales organisations an after-sales department exists. At the time of the research project, the merger had just taken place, and organisational structures were not adapted yet. Within Alfa Laval Aalborg, the after-market unit was not divided into market segments but covered all areas. Before the merger, Aalborg Industries had eight different business areas: *Marine Boilers & Heat Exchangers, Thermal Fluid Systems, Inert Gas Systems, Floating Production Systems, Exhaust Gas Cleaning, Water Treatment Systems, Industrial Boilers,* and their aftermarket business area *Global After-Sales*. This business area had approximately 50 employees globally, together with similar amounts in "freelance" service technicians. Organisationally a business unit, "Parts and service" held the company's main after-market activities, which were divided into three different areas: i) service; with regular service on-board and retrofit or upgrades of burners and boiler combustion control systems, ii) repair; sales and repair of their own and other brands of marine boilers, and iii) spare parts; for boilers, burners and automation. Furthermore, what characterizes Alfa Laval was that they used acquisitions to grow their business. They have acquired many leading marine equipment suppliers and have therefore a large portfolio of competencies. Alfa Laval had in 2012, 12 % of their sales from competing brands. This also gave the company an increased install base for after-sales services. See Figure 22

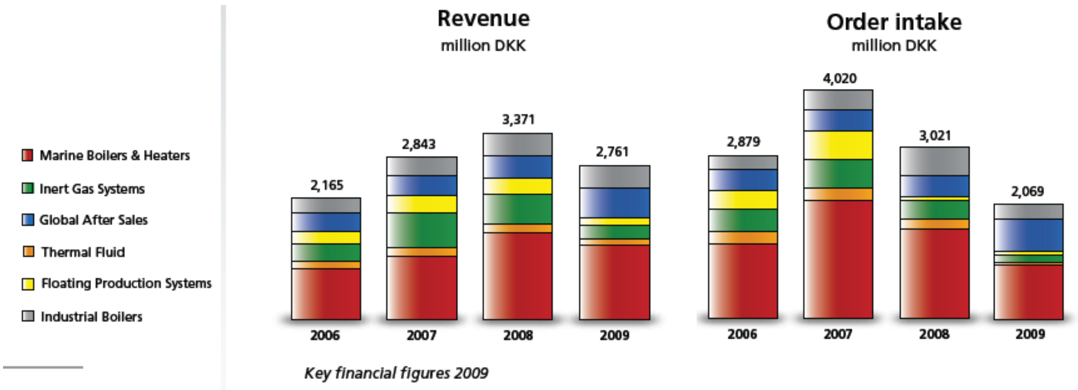


Figure 22: Annual revenue - Alfa Laval Aalborg 2009 (annual report 2009)

Just before the acquisition by Alfa Laval, Aalborg Industries' after-sales revenue consisted of 528 million DKK in 2009, which accounted for 25% of the total revenue. This high proportion of total revenue from after-sales service could be observed, despite the financial crisis of 2008, and despite the fact that all other business areas had dropped in revenue. The aftermarket across the total Alfa Laval group accounted for 26.1% of the total order intake (Alfa Laval Annual Report, 2011).

4.7.2 Product and service portfolio

Alfa Laval has specialised products and engineering solutions based on key technologies of heat transfer, separation, and fluid handling. They sell the following products: Steam boilers, waste heat recover boilers, thermal oil heaters, burners, control systems heat exchangers, inert gas systems, exhaust gas cleaning, and ballast water treatment systems.

Alfa Laval offered a broad spectrum of service offerings, with many add on services, such as: commissioning of products, inspections, condition reports, repair on-site, operator training, and overhauls. See example in Figure 23. The most interesting PSS oriented (and within the consortium unique) offerings:

Figure 23: Alfa Laval - offerings package

- *Product and service packages*: Using their broad product portfolio, they offered complete solutions, e.g. with integrated system of exhaust gas cleaning, steam capacity, waste heat recovery and heat exchangers, plus commissioning. They did not offer service agreements for all products but mainly their boilers.
- *Retrofit and upgrades*: They offered large conversions of boilers and burners, which required docking as the hull of the ship must be opened. Furthermore, they had leading technology of exhausts gas cleaning where they also offered retrofitting solutions.
- *System consultancy:* Diagnosis and consultancy of optimised systems for retrofits based on the current operation efficiency.

- *Repair on external brands*: They had large amounts of sub-brands of alternative solutions, where they offered repair of external brands and also spare part sales.
- *Academy*: In the last year of the project, they opened a large test and academy centre. Here they aimed at specialised operator training. A new product with no install base yet was sold with an add-on service as a test period had already been carried out, saving the shipowners for performance uncertainty and risk in operation.

Figure 24 illustrates the service offerings from "Aalborg Industries." The figure was an internally used overview, but it was not widely known within the organisation.

Figure 24: Alfa Laval - Service offerings

4.7.3 The development organisation

Alfa Laval launches between 35 and 40 new products every year. In 2011, 2.3 % of the company's sales were invested in research and development initiatives, with engineering activities in Denmark, Sweden, and the Netherlands. Alfa Laval Aalborg were planning (2012) to establish a development unit called '*Product and Solution Development Centre*' combining the development activities within the company, which in 2013 were cancelled due to the large restructuring activities within Alfa Laval. *"In order to ensure continued growth in this business segment [i.e. aftersales], additional focus has been placed on the development of new business concepts and products" (Annual 2009 report p. 22)*. Here, an example was the Waste Heat Recovery systems for boilers fitting after auxiliary engines. For new product development, the company used state gate models and classic development procedures, whereas there were no systematic approach for service development, despite an increased focus on the need for continuous aftersales product developments. As is seen in most of the companies within PROTEUS, the alignment of development activities between after-sales and new-sales business units, were lacking.

Alfa Laval Aalborg developed the world's largest exhaust gas scrubber with their first installation in 2009 in collaboration with MAN Diesel & Turbo on a MAN B&W main engine on a DFDS Ro-Ro cargo vessel, designed as a hybrid system being able to switch between sea water and fresh water. The product was launched as a retrofit product, but internally in the organisation at the time the aftersales opportunities of this product were seen differently. R&D saw great opportunities for after-sales to offer the installation and commissioning of the product, as this accounted half the product cost, due to the customisation in the installation process, but this was not widely accepted on the after-sales business side.

Alfa Laval Aalborg was strongly affected by new regulation for their products, where, for example, the Marine Environment Protection Committee (MEPC) of IMO agreed on a progressive reduction of maximum levels of sulphur content in fuels. Alfa Laval Aalborg had strong collaboration with sub brands within their company, other suppliers (e.g. the engine supplier MAN Diesel & Turbo), and universities, and in partnerships like Green Ship of the Future, Hercules, etc.

4.7.4 Motivation and challenges

Alfa Laval Aalborg had a strong focus on expanding their after-sales business area and had a steady development of new services and retrofit products, and one could say that the company was experienced in development of PSS offerings. At the time of the research project, Alfa Laval Aalborg simultaneously with the merger process was carrying out a parallel project for company service strategies. They were interested in remote monitoring and better diagnostics of installed equipment. Furthermore, they were aiming at integrating service and maintenance contracts better to secure the right value for the customer (PP presentation shared W). In addition, they were interested in increasing the interaction with the customer on data and knowledge sharing using new technology. Despite all these initiatives, the company held back with taking more responsibility for the equipment, with the strongest offering in this areas being "system consultancy" advising on system improvements. The company were challenged in terms of the existing low level of monitoring possibilities of their equipment. The company had developed a customised CRM (Customer Relationship Management) system where the system combined internal and external data to get a single point of reference on the customer and the installed systems, service reports, etc., plus data across customer segments for business intelligence and market reports. This provided the company with the best possible "static" data on the customer and the system installed. The company were challenged by the many project-based development projects, but this allowed them to offer customised solutions but with risk of a limited feed-back loop between the different projects and the developers of these. At the end of the research project presented at the final conference of the PROTEUS research consortium, they presented a sales tool, where they provided the sales team with a tool utilising their knowledge to estimate, based on the customer's equipment, the potential savings by installing waste heat recovery for the auxiliary engines together with a financial plan.

5.

From a PSS offerings typology to a precriptive PSS conceptualisation toolset

5. From a PSS offerings typology to a prescriptive PSS conceptualisation toolset

Entering or improving a position as an integrated product/service-oriented business poses challenges to the companies doing so in terms of navigating within a new set of satisfiers, namely that of services. This chapter presents three different elements. The first element is a descriptive study, where an industry-specific product/service offer typology is developed through a strong action-based research approach, combined with a comprehensive descriptive literature review. The second element presents a typology, which is used to describe the ten industry companies. The third element is the prescriptive study, where two normative PSS tools are presented. Finally, the chapter seeks to establish a platform for PSS conceptualisation and design methods to support the prescriptive work in the following chapter.

This chapter answers the two research questions:

RQ1: Through what terms and models can PSS offerings be described in order to support their successful synthesis?

RQ2: How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?

Developing a shared description within the research field of the outcome or the value proposition of a PSS has been approached by many authors. These descriptions are all mostly theoretical and prescriptive like: *"...Tightly coupled combination of products and services is known as servitisation ..."* (Vandermerwe and Rada 1988, 316), or *"... Solutions are more than just bundles of products and services, they are customer offerings that are tailored to suit individual requirement, often bundled into an integrated package ready to use/apply ..."* (Sharma and Molloy 1999, 2+11).

This research project has contributed to this by a comprehensive table of relevant authors for this research project and their descriptions of the "solutions." Refer to page 24 and Appendix A This supports the notion of the solutions and 'value proposition' of PSS.

Furthermore, often literature presents along with these theoretical statements examples of companies that have already made the full transition from a manufacturing company to an integrated product/service-company by describing the before and after value proposition, like[11]: "... *Danfoss from: Refrigeration, controls and sensors to*

[11] Refer to Table 2: Examples of PSS in industry after (Tan 2010) for further examples.

"cooling for food retail ..." and "... *Rolls Royce from: Aircraft engines to 'Power-by-the-hour'* ..."(Tan 2010, 11) Contrary to this, unfolding best-case examples or in general spelling out the actual combination of product and services constituting a value proposition are sparse. Only limited studies provide empirical examples. Despite the large focus on taxonomies and typologies within the research field, which is often seen in emerging research fields (Jacob and Ulaga 2008), consolidation is still needed (Eggert et al. 2011; Schmenner 2009; Gaiardelli et al. 2013; Oliva and Kallenberg 2003; Tan 2010). Furthermore, in general despite the large focus on PSS as a research field, it lacks an empirical foundation (Neely 2007; Baines et al. 2007; McAloone et al. 2010a). Large case studies, covering multiple companies describing existing PSS, have been studied in the conceptual phase of the research field of PSS. by Goedkoop et al. (1999) presented ten cases, chosen from 140 different cases, Mont (2000) presented 34 different company descriptions, and Stahel (2010) with the book *The Performance Economy* in 2006 presented numerous examples of value propositions within a Performance Economy. Despite these studies being conducted a decade ago, similar studies have not been observed.

Manufacturing companies are challenged in many ways during their transition towards an integrated product/service-oriented business, as mentioned earlier in chapter 2, Theoretical Foundation. One of the main challenges is the new design objects, which can be seen as the design of the offering life cycle and the user activity cycle. This means that the carriers of value in this system are not just a single product but a range of different offerings following and supporting the two life cycles, composing the total value proposition as discussed previously in Chapter 2.2.1 Value proposition p. 24. This changed approach of supporting the customer or the product requires a new mindset on behalf of the manufacture.

There is a need for detailed knowledge into what kind of services can be offered within PSS. This was also described by Tan (2010): *"... there's a need to establish a shared language that allows manufactures to communicate and share a common understanding of what services can be within a PSS ..." (Tan 2010, 39).* Being able to start changing business and embark on the journey, it is vital to establish a shared understanding of what the value propositions of the company are. A clear definition and an overview is also vital, as this must be implemented widely across departments, as the PSS offerings are created across product units, and departments. Galbraith (2002, 14), suggest a focus on a portfolio planning processes to approach this overview. As PSS development requires expertise from across product units and several functions at the company (McAloone 2011), it creates a need for cross-functional teams (Windahl and Lakemond 2006). The cross-functionality spans outside the "company borders" as partnering or acquisitioning strategies are part of the change, which requires a higher degree of collaboration external to the firm.

Furthermore establishing the network surrounding the PSS, an overview is needed, suggested by Cohen et al. (2006) to be made as a portfolio of product and services, to ease overview of response time and prices. The sales-department changes towards a role as sales-consultancy, and the in-field technicians as part of the customer-front-facing unit, need an in-depth user understanding. R&D designing for service needs insight into existing service procedures to optimize for efficiency. This change within the company is by many described as the journey, the transition, and the servitisation. The common understanding across these different descriptions of the phenomenon is that a manufacturing firm changes incrementally to become a more service-oriented business (Martinez et al. 2010). During this change process, an overview is needed of the current situation of the company from where a diagnosis can be made (Neely 2007; Tan 2010; Matzen 2009; Wise and Baumgartner 1999). As the PSS approach is often created within an existing business (hereof the name 'transition'), the PSS solution will be created with a basis in an existing business and its existing portfolio of offerings that require an overview of which offerings exists and which to design or re-design. This follows the resource-based view of the firm, described by Eggert et al. (2011) as the extent of strategic change depends of the service category and thereby indicates the need for developing new resources and capabilities.

5.1.1 Existing transitioning frameworks and service typologies

Building the industry branch-specific PSS offering typology was done through an action-based research approach. This section will present the literature review which was made iteratively with interventions with the industry during a longitudinal descriptive case study involving all the PROTEUS companies. Please refer to chapter 3 research foundation p. 65 to see an in-depth description of the research approach. The aim of the literature review was to get knowledge into the current frameworks to support a PSS strategy (transition), typologies that classify industrial service strategies and categories of service offerings applicable for PSS.

The study aimed at covering the in Table 17 listed parameters, where a set of 26 papers and their contributions (covering 37 different frameworks and models) has been reviewed, and analysed refer to chapter 3 for more details.

Literature review criterions	Example
Well cited authors within the field	Tukker 2004; Baines et al. 2011; Goedkoop et al. 1999; Neely 2008
Multiple research fields	Marketing, Business, Engineering design, servitisation
Min. five different representation formats	2X2-Matrix, table, list, three-diagram, model.
Both frameworks for	Transitioning: Martinez et al. 2010; Vandermerwe

transitioning, strategies and typologies, separately or combined.	and Rada 1999; Tukker 2004; Typologies: Roy et al. 2013; Oilva and Kallenberg 2003. Strategies: Davies 2004; Oliva and kallenberg 2003, and Tan 2010.
Both old and new contributions	1986: Schmenner, 1992: Silvestro, 1999: Goedkoop,2004: Tukker, 2011: Baines, 2013: Roy, Ostaeyen , Gaiardelli
Empirical based and theoretical founded	Empirical: Matzen, Silvestro, GoedkoopTheoretical: Roy, Tan,

Table 17: Criteria used in scoping the literature review

The following will detail the findings from the review. See Table 18 for an overview of all the contributions and frameworks reviewed, split into different categories to clarify the findings.

5.1.2 The change process - transitioning

Changing from a product-oriented to a product/service-oriented business is described by many as a transition process, a journey where servitisation is the goal. This is to a large extent done through a continuum with two outer poles going from pure product vs. pure service or product focus vs. customer focus (Tukker 2004; Martinez et al. 2010; Sharma and Molloy 1999; Tan et al. 2010; Vandermerwe and Rada 1988; Oliva and Kallenberg 2003; Roy et al. 2013). The aim of the continuum is to illustrate a change of focus in offerings towards the customer, which is done by either i) presenting a set of PSS categories (Tukker 2004; Clayton et al. 2012; Roy et al. 2013) or ii) a set of different service strategies (Tan et al. 2010) or a meta-cluster of services (Schmenner 1986), iii) illustrating the degree of product and service mix (Vandermerwe and Rada 1988; Sharma and Molloy 1999; Martinez et al. 2010). Furthermore, the continuum is used to serve as a strategic orientation while planning the change process (Oliva and Kallenberg 2003; Davies 2004) or as an indicator of how the change appears in the customer-supplier interface, where the interaction increases simultaneously with the coverage of more life phases (Martinez et al. 2010). The continuums were foremost used as illustrating the different offerings possible, simultaneously different elements/service characteristic were seen integrated.

The value proposition – the service offerings

Another focus for the transition frameworks included the change in value propositions, but with limited details of these most of the services was presented as meta-clusters, or archetypical PSS, leaving out actual examples. Three different forms of continuums integrate examples of service clusters. Firstly, Tan et al. (2010) present service strategies and examples of these. Secondly, Mont (2002) presents a view on PSS services. Finally, Tukker (2004) presents a much-cited framework including the eight archetypical PSS solutions. Where Mont and Tukker place their emphasis on the payment method, Tan's focus is on what to support in the service offering, as opposed to how it is financed. Despite the vitality of ensuring financially sound models within PSS offerings, this focus alone does not support manufactures to gain deeper insight into what kinds of services can be offered. The challenge of which service types to offer has been addressed by several authors, with several attempts emerging to provide an overview for manufactures via service typologies. These service typologies are represented through a variety of different formats: 2x2 matrices (Matthyssens and Vandenbempt 2008); lists (Neely 2007); tables (Ng 2014); diagrams (Mont 2002); and morphologies (Tan 2010). Despite often being rich in detail, a common limitation of most of these typologies is the use of single industrial cases as validation for the respective (Ng et al. 2012; Macdonald et al. 2011).

In the detailed study by Oliva and Kallenberg (2003), a total of 23 services are identified from a study of 11 equipment manufacturers. Common for all continuums and typologies observed, is that these are organised according to an identified set of key characteristics. Examples of such organisation include a division of services into: i) product-oriented service vs. end-user's process-oriented services; or ii) transaction-based services vs. relationship-based services. On the contrary to the above, two of the larger studies observed in Baines et al. (2010) and Neely (2007), respectively, do not cluster services. Instead these provide a measure of the services across multiple industrial cases, indicating the popularity/adaptation of the services offered among the companies.

5.1.3 Distinguishing between the offerings

The offerings were seen as distinguished between tangible vs. intangible offerings (Tukker 2004; Vandermerwe and Rada 1988; Baines et al. 2007), but this has been target for criticism (Vargo and Lusch 2004; Tan 2010). Another distinction between the offerings was found through two typologies for product services: i) services supporting the supplier´s products; or ii) services supporting customer´s action (Mathieu 2001a; Oliva and Kallenberg 2003). This was also seen implicitly in categorising the product services from a set of other categories of supporting the product across life phases, supporting the customers activities or customers business (Tan et al. 2010; Matzen 2009; Mont 2002; Baines et al. 2013). Distinctions between the different offerings were also found through different service characteristics, such as 'equipment/people-focused', looking at provision of equipment as core, or provision of contact staff as core, together with 'Product/process focus', defined by what the customer buys or how the services are delivered. Furthermore, distinguishing between whether they were transactional or relational was observed as a core part of the frameworks (Oliva and Kallenberg 2003; Martinez et al. 2010). Specifically, the interaction with the customer was also viewed for differentiating the different services (Schmenner 1986; Martinez et al. 2010). This was also described through Matthyssens and

Vandenbempt (2008), with a distinction between integration with the customer's business, and doubt 'business process integration' vs. 'technical application integration', where the manufacturer offers tailored systems.

Distinctions between the different offerings were also made through clustering the different services, through meta-clustering (Ng et al. 2012; Tan and McAloone 2006; Mont 2002; Ostaeyen et al. 2013) and archetypical PSS (Tukker 2004; Silvestro et al. 1992). Financial characteristics of the service offering were also used to cluster the services (Ostaeyen et al. 2013; Tukker 2004), which is a vital element within PSS as the ownership of the goods is often transferred to the supplier or shared among multiple users. The study by Neely (2007) presented a set of twelve service profiles arranged by different business areas of a customer, from design and development; maintenance; real-estate; finance; operation; and transportation services, but as such did not include a categorisation of the service profiles. Distinguishing between the service offerings was often achieved by using PSS characteristics.

5.1.4 Capabilities and strategies

Describing the different service offerings were done according to different service capabilities needed within the firm. Davies (2004), described a set of four main capabilities, mirroring to some extent a continuum, from manufacturing to service provision, these capabilities are described in terms of how they are positioned in the value 'stream', distinguishing whether the offerings are focused on downstream or upstream value chain functions. The process towards offering integrated product and services are described through three levels of organisational capabilities: i) grow the front end; ii) build the back end; and iii) refocus. The focus on capabilities was also featured in the study by (Matzen 2009), where an 'Offer-portfolio' of competencies and deliverables was presented and divided into three main categories: products, activities, and agreements. The framework by Tan (2009), of different service strategies was developed to illustrate how it was possible to support the customer and which development approaches was needed, which to some extent can be seen as capabilities of the company. For example, in the service strategy 'user activity services' would need competencies within service design processes. The change in capabilities and company strategies was also viewed as step-by-step frameworks (Matthyssens and Vandenbempt 2008; Davies 2004; Oliva and Kallenberg 2003; Martinez et al. 2010). Some focused on describing the change in the offerings, and others described how the capabilities needed to change. One framework in particular by Matthyssens and Vandenbempt (2008) illustrated the different paths towards three different company strategies: i) *tailored systems* through *product integration;* ii) and *process management* supporting the customer's business *acting as back-office;* or iii) a combination of both offering *turnkey solutions* acting as a system integrator. Matthyssens and Vandenbempt instruct that any move towards *turnkey solutions* must be preceded by either strategy i) or ii), above, in order to avoid high risk, and to enable radical changes of company culture.

5.1.5 Collaboration and position in the network

In describing how the value proposition changes when moving from a product-oriented to a product/service-oriented business, many of the frameworks illustrate how this had an influence on the organisational structure, like the above mentioned the strategies and the capabilities. What was a common denominator among many of the frameworks was the focus on the interaction with the customer, including transactional to relational (Martinez et al. 2010; Oliva and Kallenberg 2003), degree of customer interaction and customisation (Schmenner 1986), and how the customer is supported (Tan et al. 2010). Organisational consideration was made in connection to whether the offering was created with a front- or back-end process focus. For example, with a high level of services front-office processes are needed, and where there was a low level of services, the back-office processes are the core of the offered product/service (Silvestro et al. 1992). Matthyssens and Vandenbempt (2008), compared the offering “support to the customer’s business” as a support of the back-office of the customer, thereby emphasising where and how the service takes place.

The position in the value chain was used to describe the change in value proposition by defining the integration or focus on one or more of the value chain functions and product life phases (Davies 2004; Tan et al. 2010; Martinez et al. 2010; Roy et al. 2013). Describing the value proposition based on purely life phase integration was done by (Baines and Lightfoot 2011; Martinez et al. 2010). The focus on the positioning in the value chain was described by (Davies 2004; Neely 2008) in terms of relation to the position of the customer by a change moving closer to the customer or by integrating backwards. In general, the question whether this was internal or external to the firm was a key element when describing the change in value proposition.

	(Baines et al. 2011) 1+2+3+4	(Martinez et al. 2010) 1+2+3	(Ng et al. 2012) 1+2	(Tukker 2004)	(Sharma and Molloy 1999)	(Vandermerwe and Rada 1988)	(Mathieu 2001b)	(Oliva and Kallenberg 2003) 1+2+3	(Davies 2004) 1+2(Davies et al. 2006)3	(Matzen 2009)	(Neely 2008)1+ (Neely 2007)2	(Silvestro et al. 1992) 1+2	(Schmenner 1986)	(Tan et al. 2010)1+(Tan and McAloone 2006)2	(Mont 2000)1+(Mont 2002)2 (Mont 2004)3	(Goedkoop et al. 1999)	(Matthyssens and Vandenbempt 2008)	(Roy et al. 2013)1+2	(Ostaeyen et al. 2013)	(Clayton et al. 2012)	(Gaiardelli et al. 2013)
The change process																					
Organisational change	❸	❶					○		❸				●								
A transition-ning continuum	① ❸	② ❸		●	●	○		❷						❶				●		●	
Step-by-step approach to servitiza-tion		❷						③	③								○				
The value proposition																					
Services popularity at customers		❶	②																		
Product life phases	❸	❸							❶					❶ ❷	❸						
Distinguishing between the services																					
Typology: List of services possible (theoretically)	❹			●			●	①	❶					❶	❶ ❷ ③			②			○
Emphasis on payment method	❹			●						●					❸			❶	○		●
Distinguishes customer & product services	❹			●			●	❶		●		❷		❶	❸						●
List of services found in industry (empirical)	②		①				●			○	②					●					
Meta-clustering of services (service categories)	❷ ❹	❶	❶		●			❶ ❸	❶ ❷	●			○	①	① ②		●		●		
Characteristic of service described	④				○	●			❶			① ❷		②					●		
Identifying a set of archetypical PSS		❷		○							①	②				○		①	○	○	●

Industry examples												❷	●			●					●
Capabilities and strategies																					
Capabilities	❹	❶							②					❶							
Strategic consideratio ns		❶						② ❸	❶ ❷ ❸					❶ ❷			○				
Method for identifying different service attributes		❶	❶							●				②					●		
Collaboration and position in the network																					
Front & Back end	❷								❸			❶ ❷									
Customer relationship change		❷						❶	❸				●	❶							●
(Degree of) vertical integration	③	③						❸	①												

Table 18: Overview of PSS-offerings frameworks

Table 18 has five main categories and subcategories in each of these. The numbers refer to the figure of the author, if no number is listed only one figure is provided from the author. The main focus of the framework is marked as 'red none-filled', and the 'black-filled' dot is a focus area of the author.

Summarising the need for a focus on services typologies, service strategies, and transitioning frameworks:

- There is a lack of a shared and common understanding of what services can be within a PSS (Tan 2010; Gaiardelli et al. 2013).
- There is a need for a consolidation of the different services described in literature (Eggert et al. 2011; Schmenner 2009).
- PSS terminology needs to be strengthened (Baines et al. 2007).
- Consolidation of services is seen as a way to strengthen existing services – to increase efficiency, quality, and delivery time (Oliva and Kallenberg 2003; Gaiardelli et al. 2013).
- A clear definition and an overview are vital as PSS is created across departments and product units (Galbraith 2002; Windahl 2007b).
- Little work has been done in trying to operationalise the SD-logic (Ng et al. 2012).

- The current *position*; and its details on the product/service portfolio - is crucial as baseline for any changes towards a new PSS strategy (Martinez et al. 2011a).
- Development of new services, or improvement of existing services, needs unique development approaches together with an overview of possible service strategies (Tan 2009).

5.2 Development of an industry branch PSS offering typology

Together with the needs found in the literature review just presented, detailing the aims of the different contributions reviewed served as a platform for formulating the research propositions from which to develop the typology and choose a framework to bring a context to the typology. This section presents the activity of investigating how a PSS typology can be transformed to be able to support PSS synthesis.

The different contributions and frameworks reviewed had many different aims, spanning decision tools for strategy considerations to an overview of unique services within a company or industry. Alongside this, the research design, method, and transparency differed among the frameworks and typologies.

- *Mostly descriptive*: What characterised multiple models was that they were descriptive, bringing, e.g. a detailed list of services found either by industrial investigation or by literature studies.
- *Usage:* The models and frameworks were mostly aimed at academia as receiver. They were not developed or transformed into tools to be implemented and used by industry practitioners.
- *Research method*: The research methods used in the studies were difficult to find, and for some contributions they were left out.
- *Cross study approach:* A few of the frameworks listing services or presenting typologies used a cross study approach, integrating previously studies. Typologies were more likely to have in-depth industrial cases but not generic validation through cross-case testing. Empirical studies across multiple firms were sparse, with most mappings created with a basis in one company.
- *Conceptual frameworks:* The continuums that represented meta-clusters of services or archetypical PSS were mostly conceptual frameworks. With a lack of detail on how they were developed, they were merely illustrating a proposition within the research.
- *Validity:* Most of the continuums were conceptual or theoretical methodologies lacking thorough industrial validation. Furthermore,

most typologies and frameworks were prescriptive, with origin in literature and with no or little validation through empirical testing.

- Lastly, a comment directed to the inconsistency in literature when referring to; transition framework, strategy and archetypical services, made the landscape blurry, also complicating the literature search.

Two studies were distinguished by their use of a large data sample from multiple cases with the aim to cover a whole industry. This made them particularly interesting for this research project. They will be elaborated to position the work in this thesis:

Covering 10,000 firms' adoption of services: Neely (2007) created a large longitudinal empirical study aiming to identify to what level manufacturing companies had servitised their business and particularly what services they had adopted. The study used a publicly available database (OSIRIS) where financial data was gathered from approximately 10,000 firms using data sets from three different years 2007, 2009, and 2011. The twelve service profiles were found through coding manually 50 firms, whereof a code was developed, which was tested on the manually coded firms, refined, and used for the whole set of 10,000 companies. See Figure 25. The size of the data sample was the strength of the study, but the method for extraction included a key limitation and a key decision:

- Those firms that reported their service revenues separately from product revenue were not represented within the data sample.
- Companies smaller than 100 employees were not included.

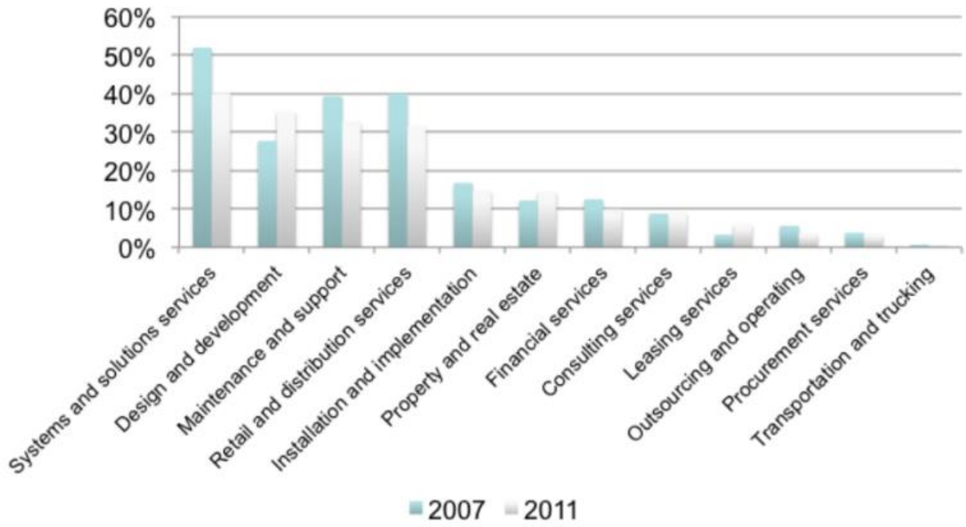


Figure 25: Services offered based on a study of 10.000 firms (Neely et al. 2011, p. 9)

UK manufacturing firms adaptation of services: Another large empirical study conducted by Baines et al. (2010) explored the adaptation of service by UK manufacturing firms. Similar to Neely´s study, the focus was not on the environmental benefit but on the finance of each service, together with a set of extra elements. As the study format was a survey, it allowed services which were not charged separately to be accounted for, together with their popularity among the customers. The study covered thirteen different services (see Figure 26) charted together with the customer perceived value of these. This study was unique as it integrated supplier and customer in one data set. This survey compared to the above study detailed the service activities, and did not create service profiles. There was no categorisation of the activities; they were purely ranked based on the popularity amongst the respondents (the customers). The popularity ranked the service offerings into poles creating a continuum going from services tending to be protective of business towards services tending to be proactive of winning business.

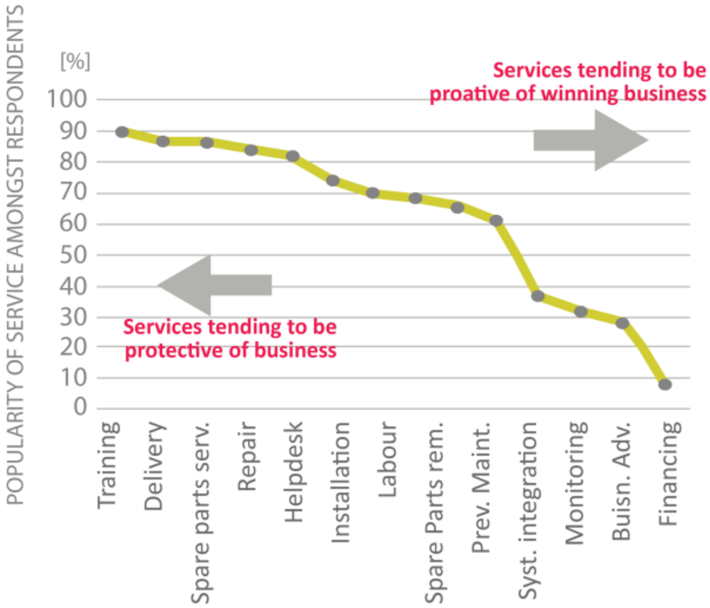


Figure 26: Range of services adopted by manufacturing firms in UK (Baines et al. 2010) graph modified

5.2.1 Selection and adaptation of a framework

Instead of developing yet another framework, the study charted in this thesis deliberately took point of departure in searching and selecting an existing framework; the chosen framework was the model presented by Tan et al. (2010), where different service strategies are placed on a continuum with two outer poles, namely product-oriented and customer-oriented strategies (see Figure 27). Spanning a focus from the product to the user of the product all the way to the business of the customer, the different categories presented in the model do not represent a sharp distinction between the types of services. The transition within this model is seen as fluid, where a manufacturing company offers these services in any constellation. The model is also chosen due to the implicit focus on capabilities needed within the company for each service strategy. Describing this by stating the development approach for each strategy, e.g.

a focus on the product, needs an engineering design approach, whereas customer activity services need softer skills, such as e.g. design for service. The model is purely developed through a theoretical study, which was taken into account when planning for the adaptation of the model, for validation.

The framework chosen includes;

- Coverage of multiple dimensions and characteristics of a PSS.
- A visualisation of a continuum, bringing awareness of different development strategies for the different PS-offerings.
- Service meta-clusters.
- Overview of single services within each cluster.
- Unique PSS capabilities needed.
- Emphasis on fluidity between categories.

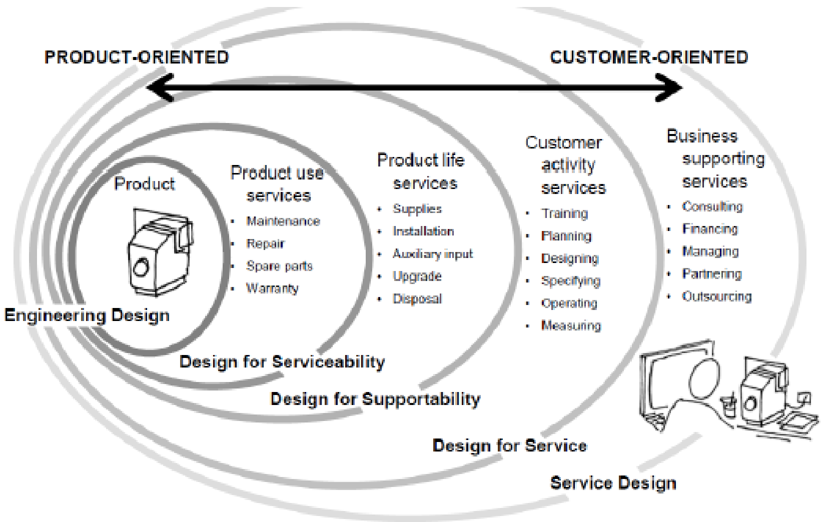


Figure 27: Framework: Service strategies (Tan et al. 2010)

5.2.2 A Product/Service-typology for the maritime industry

This section will detail the offerings found and charted. To support a practitioner usage of the industry product/service typology, it was supported by the development of icons for each offering. This was made in close collaboration with all researchers in the consortium. See the overview of all the offerings and a detailed description of each in Figure 27. Figure 28 illustrates the graphic presented to the companies in Workbook #1. (Mougaard et al. 2013).

Figure 28: The PSS offering typology presented to the companies in workbook #1: Maritime Branch analysis.

5.3 Synthesis of a whole industry branch - PSS offerings typology

This section presents the Product/Service-offerings found in the PROTEUS companies by elaborating on each offering in the context of the companies, together with theoretical reflections. Refer to Figure 29 for an overview of all the offerings charted. The study of the 'servitisation level' in the industry in connection to the advancement in services offered to customers was part of a large descriptive study of the consortium and the Danish maritime industry. All findings were published through the PROTEUS workbook series as the first workbook entitled Workbook #1: *Maritime Branch Analysis* (Mougaard et al. 2013). This section investigates the applicability of the PSS offerings typology to describe an entire industry branch.

5.3.1 Products

The majority of the consortium companies (seven out of ten) were manufacturing engineering companies, producing and selling physical goods. A single company, a purely consultancy firm, did not offer physical products but offered consultancy (e.g. noise and vibration reduction). What characterised the manufacturing engineering companies was their wide product range and coverage of different market segments. What distinguished the product offerings were the application areas and the criticality of the product/system offered. The value delivered through the product was connected to different need and function areas on the ship (e.g. propulsion, cargo, electricity, safety, compliance, and energy efficiency, just to mention a few). All products were highly integrated on the ship, with examples like Alfa Laval Aalborg with heat exchangers and waste heat management, and MAN PrimeServ Frederikshavn with the propulsion system. Also, Klinger with their valves and gaskets and YIT with their cabling and control systems had commodity products, together with complex services, such as installation and later problem identification. These two companies were examples that the Total Cost of Ownership cannot solely be determined by looking at one product within an integrated system, but rather the interconnectedness of the total system must be taken into account because the context of the product might bring unforeseen criticality of even small components.

Monitoring equipment was offered by six of the consortium companies – not necessarily the same companies offering services handling the actual monitoring (e.g. remotely). Many of the companies were focusing on 'digitalizing' their products, and it was observed that if the products were merely static (i.e. not including wear parts) they might rely on other products' condition monitoring data. Furthermore, some products on the ship did not have aligned running hours with the ship, for which reason companies sought opportunities for integration with products/components that were monitored, in order to be able to better support the product during its use. This trend among the suppliers to increase monitoring opportunities, also described by Neely (2007, 2), creates an opportunity to exploit the potential of 'informated products'. Oliva and Kallenberg (2003) also point to this trend as a system approach, which allows the suppliers to gather data realizing the size of the service market and account for the contribution the services will have on the company's operations. Emerson Process Management had acquisitioned a technology company allowing the company to offer a package including monitoring equipment.

5.3.2 Product use services

All the suppliers were supporting the product in use, which were any services or product offered in the use-phase of the product equal the ship being in commission. These services focused on the end application of the customer and were additional to the product, as a support to the product. This can be viewed as 'service in addition to product' (Brezet et al. 2001). One way to describe these services is also defined as 'Technical application integration' (Matthyssens and Vandenbempt 2008). Which essentially is any additional processing, programming, assembly to 'install or commission' the product. These services reflect the capability of the company to support the operation/use of the product/system and not the company's manufacturing capabilities where they origin (Davies et al. 2006).

The most common Product Use Services were the Product Manuals, Certificates, and Warranty. All of the consortium companies (except the consultancy firm) offered these, and all of which had tightly coupled regulation connected, requiring these services as an integral part of offering the products. Extended Warranties were offered by two of the companies (the later selected case companies MAN PrimeServ and Alfa Laval Aalborg) this indicated their 'motivation' and 'capability' to take guaranteed/ contracted greater risk and responsibility of the product use. This trend could have a negative effect on the companies' service business because Warranties do not include a proactive approach to customer satisfaction and furthermore cause contradiction internally in the firm as the warranty departments often were connected to new-sales and not after-sales (observed at these two companies), This could possibly lock out potential sales of service agreements, where greater customer satisfaction and profit can be found. Warranty management is argued to be a strategy towards PSS to offer efficient result-based PSS. (Sundin et al. 2010). Sundin et al. (2010) refer to the distinguishing between promotional or protective warranties (guarantees) and point to the fact that warranties are much different to make, concerning product warranties and service warranties.

Another offering found was Digital Product Manuals, offered by three companies, where only MAN Diesel & Turbo offered these through a partnership with a technology firm, using a standard format, though this was offered only for one of the company´s product groups (as the offering had not moved across company divisions). All of these offerings (except Extended Warranty) were not charged.

Offering Spare Part Services was observed as the biggest source of after-sale revenue, a ‘cash cow’ for many of the company’s after-sales business. Seven companies offered Spares on Demand, and two companies offered Spare Part Exchange services (MAN PrimeServ with reconditioned turbochargers and crankshafts and YIT with a large portfolio of spares, including a wide range of suppliers, covering multiple suppliers in the consortium). The Spare Part Services had many variants, and Financial Services for these were found. Within Spare Parts agreements, it was discovered that reconditioning/repair was an essential activity for offering spare part exchange programs, where customers are pooling a set of spares between their own ships (with ownership of spares) or between different shipowners (ownership of spares at the supplier). The element of sharing is seen as vital in PSS (Mont 2004) by optimising resources, which are seen in many PSS frameworks where the environmental efficiency is a largely integrated element. Sharing can be differentiated through how the sharing is made possible. The customer goes to the product, or, the opposite, the product goes to the customer (Mont 2004). This is better understood in B2C PSS,[12] but within B2B PSS a spare part exchange program can be seen as an example thereof.

Two companies (the case companies) Alfa Laval Aalborg and MAN PrimeServ Frederikshavn offered spare part kits, which is a classic example of bundling as a marketing strategy to sell a ‘package’ (e.g. in OM as operation support) (Neely 2007; Grönroos 1994). These two companies offering larger integrated systems had many suppliers that put them in a position to sell packages covering many links up the supply chain. Bundling these spares secured them the sales and further created possibilities for fast service repair.

These offerings (together with the ‘product offered’ previous category) can be categorised as passive services (e.g. information delivered to the customer, as promises for future services, or information given to support product use). Also, spare parts are static and delivered to be used. These services distinguish themselves by the value created in the exchange. Ng et al. (2012) described this as ‘operand resources’, resources which are passive and to be used (Vargo and Lusch 2004).

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[12] An example is the Laundromats (going to the product) or leasing a washing machine (product comes to you)

The corrective services were found at the companies which had high-cost products. The consultancies firm Lloyds ODS and the commodity firm Klinger Danmark were the only companies not offering Repair Services. Klinger Danmark's low-cost products would be replaced and not repaired.

Another corrective service was reconditioning, which was offered by five of the companies and spanned many product groups. Hempel with paint and coating expertise offered preparation of the hull in dry-dock for re-painting. Pres-Vac Engineering offered reconditioning on their Pressure/Vacuum Relief Valves, which had the function of a safety instrument, balancing any pressure within the tank of the ship and its surroundings. MAN PrimeServ, as mentioned above, offered services with their turbocharger and crankshaft. These three companies are examples of how the terminology is covering quite different service processes but with the same benefits delivered to the customer.

The Preventive maintenance Time/Count-Based Services and Condition-Based Maintenance were offered by many of the companies. Limitations were found in the product groups that were less mechanical with no moving parts and/or products that were not operating full-time in the ships operating time. This is why running times were difficult to estimate. Here the companies were relying on statistical data or on collaboration with the surrounding system (other suppliers) to base their decisions on the overall 'system' performance/condition.

What was important to distinguish between here was the element of off-shore and on-shore activities. The Condition-based Maintenance was offered by six companies, where only two of these were handling this proactively by remote access to the condition (e.g. Hempel had a collaboration with a technology company FORCE, where based on real-time fuel consumption they could propose a re-paint with a promised defined increase in efficiency). PresVac Engineering and Emerson MTM both offered monitoring equipment to the crew allowing them remotely (e.g. on the bridge) to control and monitor the system by tracking changes in key indicators through alarms. Though none of these companies were offering condition-based service remotely but through a service activity, they would use the condition information in inspection or repair activity, taking a partly proactive service approach.

Distinguishing between on-site and off-site was also observed in the case study by Ng et al. (2012) as an attribute to two of their eleven value creating service activities, namely Equipment Maintenance Service and Equipment repair service. Furthermore, the Maintenance services in their study were corresponding to Time/Count-based and Condition-Based maintenance services as scheduled or preventive services, and repair was the activity of fixing a broken part/product. These services were offered through 'pay as needed', which is similarly found in the study by Martinez et al. (2011a), Within their study, they described the add-on services as 'pay as needed' and standardised and therefore requiring a low intensity relationship. This might not be the case for all the services offered within this category.

5.3.3 Product life services

These service strategies are covering a holistic view including before, during, and after use services (Vandermerwe and Rada 1988) keeping the object of focus the product performance (Schmenner 2009) also dubs product process services (Matthyssens and Vandenbempt 2008). Also described by Davies (2004) as migrating value base, by going up or down the value stream. The supplier takes into account the total product system and offers support during the whole product life cycle by looking at various product life phases and not just, for example delivery and installation but also operation and end-of-life services (Tan et al. 2010). Through-life support services (Product Life Services) with examples like installation and commissioning services and all the maintenance services; Upgrade, Retrofit, Take-Back is still value by exchange, through add-on services, and still with a focus on the product/system but with an expanded view including multiple life-phases. They are distinguished from passive services as they have an effect on the system caused by the supplier.

An Upgrade of the system was observed at seven of the companies. The service process could be similar to that of reconditioning, with the difference being the increased product performance as the main focus for upgrades. Upgrades also included swapping existing products with newer versions. Emerson MTM expressed the problematic situation that an upgrade can put a supplier in, as a whole system change can open up opportunities for the customer to change suppliers after screening the market before deciding on the final upgrade. Similar to upgrade in the focus on product lifetime extension or function improvements, were retrofit services, which were observed at six of the companies. Unique for retrofit was its focus on improvements connected to matching new regulations to stay in compliance by retrofitting existing product/systems on board or making new marketed products fit existing applications/ships. Furthermore, retrofit solutions were observed as an engineering task involving adjustments/re-design in conjunction with existing systems, whereas upgrades were merely seen as an installation activity or a light version of retrofits. These two services had different degrees of improvements of a product/system, which was also seen in the case study by Ng et al. (2012), where a value creating activity such as equipment performance was detailed by two attributes: i) meet desired equipment performances; or ii) exceeds the desired equipment performance.

Three different types of installation were observed where installation was the regular process of installing the product sold (could be both in new-sales and after-sales), conducting a repair activity, and demounting the old product and installing a new product. This was observed at seven of the companies. Still with a focus on the performance of the system, installation consultancy was observed at five companies advising on the installation. An example was Hempel with their Coating Advisors facilitating the coating process, another example of this was YIT with their large interconnectedness between all systems through cabling and electro-technical solutions on-board they offered all three types of installation services.

The two service offerings, installation and delivery, are examples that products have always been accommodated with a set of services but not until late 1880 handled by the manufactures (bypassing) or integrating with wholesalers (Schmenner 2009). In the Maritime industry as an international reaching industry, these two services (or all services on-site) change from simple to complex as the shipowner organisation is a globally reaching company with shipping routes all over the world. This challenges the suppliers in any of the on-site / off-shore activities as logistics and infrastructure becomes increasingly essential elements, which not all suppliers can manage easily.

Only MAN PrimeServ Frederikshavn were offering take-back systems and thereby focusing on the disposal (post use phase). They also offered both Spare Part Exchange services where the take-back activity was an essential part, as the distribution/shipping capability is an important element of the offering. A take-back activity is vital within a PSS and connected directly to three of the PSS characteristics mentioned by Tan (2010), including 'availability of offering'; 'revenue mechanism'; and 'resource efficiency'; where the closed material loop is directly connected to take back systems. Take-back systems are a core element of the environmental efficiency of a PSS system and are a way for suppliers to make recycling become more profitable, thereby an encouragement for manufactures to design products with high recyclability (Mont 2002).

5.3.4 Customer activity service

Customer activity services focus on the user of the product instead of the product it-self (Tan et al. 2010). The focus is placed on the activities that the user goes through, which can be before, during, and after the customer has acquired a product/system (Vandermerwe and Rada 1988). The focus is on the processes of the customer, and the offerings are concentrated around delivering competencies and resources supporting these (Grönroos 2007). With long-life products, manufacturers interact with different departments within the customer-organisation, and furthermore in a B2B context this can be spread (appear multiple times) across the different supply chain *functions. The customer portfolio becomes evidently more important when moving towards a more customer-oriented business. Within larger organisations, and particularly in B2B and long-life products, it is important to approach the customer-organisation carefully, which according to Sheth et al. (2004) can be done by distinguishing between customer, buyer, and user.*

The strategies of Customer Activity Services therefore cover, and should take into account, customer, buyer and user. Within the maritime industry as described in chapter 4 there are many different customer organisations (customer types), and naturally with the relationship between shipyard and shipowner there is a change in buyer and customer, bringing great challenges for the TCO approach.

Services in pre-use can be specifying and designing (Tan et al. 2010), and as Mont (2004) defined it using two areas: i) support services during design, production, and transportation; and ii) service at the point of sale. Design support services were offered by all ten companies and covered broad planning, specifying and customisation of a new system development, and were connected to customisation of larger product packages, as these would be an integrated part of the ship, thereby requiring many descriptions on the preferred design. Lloyds ODS offered design solutions (e.g. noise and vibration reduction for existing ships and acting in collaboration with ship-architects). Many of the companies offered product/systems that required a certain level of customisation (e.g. Novenco FF with a piping system designed specifically for the ship; Emerson MTM with their Tank Management Systems; and Alfa Laval with their boilers).

Another way to support the customer was observed as the suppliers were creating Product-packages which can be seen as part of design support. These services are focused on the system integrator, which is seen as a key capability of a PSS supplier (Davies 2004). This can be seen as a core offering within a PSS, as the product are no more a single unit but part of a larger integrated system, which often demands a network of suppliers in development, production, and operation (Matthyssens and Vandenbempt 2008). The integration can be with a focus on a bundling approach, which was observed at YIT and Emerson MTM. This is often seen when a design has been dominant and widely accepted (Matthyssens and Vandenbempt 2008). Here, the product functionality and standards are defined, and the value adding activities are created through packaging and marketing of these. The packaging can be around a function area (e.g. Tank Management) or a need area (e.g. safety, environmental regulation). These product packages support the customer in purchases as they ease the purchase process, thereby minimising the activities for procurement. The packages also support the customer in any related afterlife phases as a larger group of products has one reference supplier (warranty, spares, and maintenance). In this way, the services can also be viewed as "bundled." The package offering are connected directly to a specific characteristic of a PSS, namely 'degree of integration' (Tan 2010), where the value constellation is characterised by: i) core benefit alone; ii) multiple benefits aggregated; or as iii) multiple benefits integrated. This describes exactly the above mentioned examples, which are not single benefits but a variation of the two later mentioned aggregations and integration of benefits.

Training was offered by six of the companies, directly aiming at supporting and enhancing the competence level of the user. This was performed in many ways. The larger companies, MAN PrimeServ and Emerson MTM, offered these through internal resources, whereas the smaller companies like NoreqActa partnered with a service partner, offering training through an external network. Training could be offered during sea trial or through single modules on-shore. Some of the training programs spanned longer periods, covering multiple modules. This is why they required more coordination as the crew were at sea and spread globally.

Training Other Companies' Technicians was offered by four of the companies. Hempel had the most advanced academy, as they would sell certification courses for coating advisors to their competitors. Offering training of other companies technicians (could be competitor and external service network) can put customers in contact and business at risk, which was observed by Cakkol (2013) with a manufacturer and their external dealer network. Only a few of the suppliers were making business around academy offerings, while the rest offered training as an integrated part of a service package together with product sale, and many of the systems required (by regulations) training to operate. Preparing for offering training and building the academy was observed at the larger companies to start internally, with building training programs for their own service technicians, and initiate competence profiles for each technician, to make the selection precise, choosing the right specialist for the right service task, minimising time used and optimising service quality.

Offering support to daily practice on the ship through remote assistance for operation, repair procedures, or urgency matters was offered by all of the ten companies, through offering a Service Technician On-Call to the crew, or technical department of the ship-organisation. Not all of the companies had dedicated service technicians as part of a call-centre. Some allocated the calls among different departments. Some combined multiple functions in the company, like 'sales/technicians' or 'workshop/ technicians'. Offering Service Technician On-Call was difficult for the companies to charge, as many customers perceived this offering as part of the product cost. Some suppliers made customer segmentations and could by this manage who to charge and whom not to charge.

Supporting the user of the product was seen through the two above services (Training and Service Technician On-Call) as a direct interaction with the customer and making the customer smarter. Also, this was observed through services aimed at improving the information level on the system, through the two services: i) Shared Management System; and ii) Management System, where information was stored for the customer to gain a greater knowledge foundation to act upon. The suppliers also benefitted from these services, as communication was eased through the crew or technical department having better insight into the system, through previous service jobs, service logs, or maintenance descriptions.

Digital catalogue services were offered by two companies. The catalogue was developed by Klinger DK as a result of being notified by a shipowner on a top ten list of critical component manufactures, not due to the criticality of the actual product but in the time for identifying the component, which can for some product groups be difficult, due to the placement of the product, or lack of identification code. Supporting this activity of part/product identification follows Tjiparuro and Thompson (2004) set of most important Design for Maintainability principles: simplicity; part features; operating environment; part identification; and assembly/ disassembly.

Customer Activity Services support the customer in specific activities, opposite the above examples, these were observed as the suppliers were taking over some function-areas/activities normally taken care of by the customer and even simultaneously taking greater responsibility, where the latter was observed the least. Supporting the customer in planning is an example of an area of the customers activities where a whole set of activities are taken over by the manufacturing company/suppliers. This was observed at six of the companies as they offered planned overhaul, where support is offered to plan maintenance schedules. Multiple systems on the ship required dock or even dry-dock activities, which made it even more vital to plan the maintenance activities. Some overhaul activities require unique workshop facilities, and this is why the components are shipped/ transported to a location with the right equipment and personnel. This is why logistics and transportation/infrastructure became important and needed new skills from the supplier's side. In PSS, the infrastructure is widely described as a critical element within describing and evaluating a PSS (Mont 2004).

Diagnosis plus Recommendation services were offered by five of the companies, while On-Site Inspection services were offered by nine of the companies. These two services as distinct from the first mentioned do not necessary need an on-site presence, whereas the latter mentioned needs an onsite presence and it is often connected with a repair activity. Again, this is reflecting the challenges the suppliers face in offering add-on service separate from other offerings. Offering diagnoses and recommendations for future actions, and not the actual service repair job, was hard for the suppliers to charge.

The most advanced service offering within the Customer Activity Services was found at MAN PrimeServ with their Remote Monitoring and Operation service, where they in collaboration with the crew/technical department offered preventive maintenance to optimize real-time the performance of the system. Proactive services like this were offered only by three of the companies: the two case companies, Alfa Laval Aalborg and MAN PrimeServ Frederikshavn, and Hempel. This was surprising as all companies were aware of the change in market condition, but few were actively trying to capture the new after-market opportunities through proactive approaches.

5.3.5 Business supporting services

The last service strategy is Business Supporting Services, which is all the services that directly aim at supporting the customer's core business, characterised by the responsibility areas normally placed at the customer changes to be the supplying company's responsibility (Tukker 2004) often with a predefined price and period of time (Roy et al. 2013). Result-oriented PSS defined by Tukker (2004) would match this strategy. This strategy links closely with Customer Activity Services and is distinguished by its focus on the customers' business, covering multiple business areas and not on the single processes and activities.

Management of Maintenance was an example of the supplying company overtaking responsibility for managing and delivering regular maintenance activities, which were offered by three of the companies (YIT, Hempel and MAN PrimeServ. These were distinct in terms of how much responsibility was transferred and if the contract involved a fixed periodic price. MAN PrimeServ was the only company offering this for all services connected to their system; they only offered this for certain product and customer groups. YIT and Hempel offered Management of Maintenance for single larger service activities, and offered these broadly to all customers. Financing was offered only by MAN PrimeServ. This was part of the Management of Maintenance service, which is often seen as an enabler of certain services. Larger retrofit solutions were an example thereof, as this was often seen accompanied with financial services as the upfront costs were cut down and unforeseen expenses removed and replaced with a flat-fee agreement. Financing single offerings product or service packages with a hire purchase was also observed. In these instances, the ownership also remained at the customer.

System consultancy was offered by six of the companies, covering all the larger companies plus the two service-oriented suppliers YIT and Lloyds Register ODS. None of the smaller manufacture companies offered system consultancy. This was characterised by covering multiple activities spanning both shorter and longer time periods, and interestingly this offering emphasised the fact that when offering Service Supporting Clients (SSC) business it is possible for the supplier to service other suppliers' products which was the case for all these suppliers. This distinction is broadly used in PSS literature, for example, in (Mont 2002; Mathieu 2001a).

Project management was offered by five of the companies. This included some of the smaller companies like Novenco FF and Pres-Vac Engineering, and was mostly characterised by a single activity but also including service on other supplier's products. Novenco FF managed total design and project facilitation taking into account customers' need for a fire fighting system. Another example of project management was the service network in Frederikshavn, where they would offer services covering all maintenance activities connected to, for example, an overhaul. All the three above services are directly connected to consultancy offerings.

Service agreements were offered by all companies except one. Service Level Agreements were understood as a contractual agreement for a specific service offered, depending on the company different elements were specified. Maintenance schedules were used to state both customer and suppliers responsibilities, this could be, for example, frequency and type of maintenance conducted and by whom. This service is a passive approach to influence the behaviour of the user of the product. When the supplying company would take over a greater part of customer's business, the agreement was seen to change in nature from service-level agreements to performance agreements, where a certain performance of the system delivered was guaranteed. This is also termed 'performance contracted' result-oriented PSS, where a certain capability is sold (Roy et al. 2013). The service agreements allowed for upgradable service selection, where service schemes were providing 'like a car-wash model' an overview of which elements could be selected, also understood as service added in literature (Vandermerwe 2000), this was offered by three of the companies – MAN PrimeServ Frederikshavn + Emerson MTM and Hempel.

Refer to Figure 29, for an overview of all the offerings found. See a detailed description of each offering in the table in Appendix C: Table with typology for PSS offerings.

	YIT	Presvac	NFF	NoreqActa	Lloyds	Klinger	Hempel	Emerson	Aalborg	PrimeServ
Products	●	●	●	●	○	●	●	●	●	●
Monitoring equipment	●	●	●	○	○	●	○	●	○	●
Time / count-based maintenance	○	●	○	●	●	●	●	○	○	●
Condition based maintenance	●	●	○	○	●	○	●	●	○	●
Repair	●	●	●	●	○	○	●	●	●	●
Trouble shooting	●	●	●	●	●	○	●	●	●	●
Reconditioning	○	●	●	○	○	○	●	●	○	●
Spare part kit	○	○	○	○	○	○	○	○	●	●
Spare parts on demand	●	●	●	●	○	○	○	●	●	●
Spare part pitstop	●	○	○	○	○	○	○	○	○	●
Spare part owned by suppliers	●	○	○	○	○	○	○	○	○	●
Spare part owned by the customer	○	○	○	○	○	○	○	○	○	●
Product manuals	●	●	●	●	○	●	●	●	●	●
Digital product manuals	○	○	●	○	○	○	○	●	○	●
Technical documentation	●	○	●	○	●	○	●	○	●	●
Certificates	●	●	●	●	○	●	●	●	●	●
Warranty	●	●	●	●	○	●	●	●	●	●
Extended warranty	○	○	○	○	○	○	○	○	●	●
Delivery	●	●	●	●	○	●	●	●	●	●
Installation of products	●	●	●	●	○	○	○	●	●	●
Installation consultancy	●	○	●	○	○	○	●	●	○	●
Installation of other companies' products	●	●	●	○	○	○	●	●	○	●
Upgrade	●	●	○	●	○	○	●	●	●	●
Retrofit products	●	●	●	○	○	○	○	●	●	●
Commisioning / sea trial	●	●	●	●	○	○	○	●	●	●
Take-back system	○	○	○	○	○	○	○	○	○	●
Academy	●	○	●	●	●	○	●	●	○	●
Training other companies' technicians	○	○	○	●	●	○	●	○	○	●
Reciprocical training	○	○	○	○	○	○	○	○	○	○
Digital catalogue identification support	○	●	○	○	○	●	○	○	○	○
Management system	○	○	○	●	○	○	●	●	○	●
Shared management system with customer	○	○	○	○	○	○	●	○	○	●
Service technician on-call	●	●	●	●	●	●	●	●	●	●
On-site inspections	●	●	●	●	●	○	●	●	●	●
Diagnosis plus recommendations	○	●	○	●	●	○	●	○	○	●
Proactive contact	○	○	○	○	○	○	●	○	●	●
Remote monitoring and operation	○	○	○	○	○	○	○	○	○	●
Planned overhaul	●	●	○	○	○	○	●	●	●	●
Service kits	●	●	●	●	○	○	○	●	●	●
Design support	●	●	●	●	●	●	●	●	●	●
System consultancy	●	○	○	○	●	○	●	●	●	●
Management of maintenance	●	○	○	○	○	○	●	○	○	●
Financing	○	○	○	○	○	○	○	○	○	●
State of the art deals	○	○	○	○	○	○	○	○	○	●
Product leasing for repair task	○	○	○	○	○	○	○	○	●	○
Project management	●	●	●	○	○	○	●	○	○	●
Service agreements	●	●	●	●	●	○	●	●	●	●
Upgradable service selection	○	○	○	○	○	○	●	●	○	●

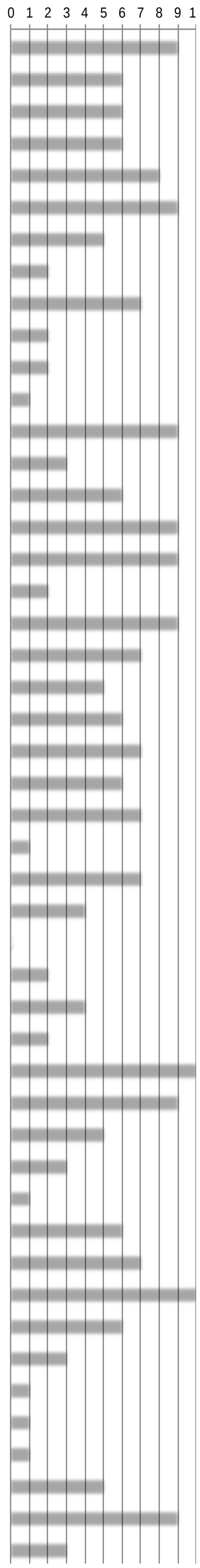


Figure 29: PSS offerings found and charted at each of the ten companies of PROTEUS. Black dot = found. White dot = not found. The right side graph summarises the number of offerings found across all companies.

5.4 From typology to conceptualisation tools

This section elaborates on PSS conceptualisation by reflecting on existing PSS conceptualisation frameworks. The goal of describing PSS conceptualisation is not to start a discussion, but rather the aim is to illustrate how PSS conceptualisation has been understood within this research project and to bring a context to the reader and to the validity of the research project. This section seeks to investigate how PSS conceptualisation can be defined.

Conceptualisation of PSS is distinct from traditional engineering design and product development methods and tools as the focus on the product has expanded in several areas (McAloone and Andreasen 2002; McAloone et al. 2010a; Mont 2002; Manzini et al. 2004). As discussed earlier in chapter 2 theoretical foundation the changed design object is described by the use of a set of dimensions[13] from which a PSS concept can be described, evaluated, and conceptualised. The key of the conceptualisation in PSS is iteration, to take into account all the different aspects and perspectives of a PSS. The focus in PSS conceptualisation is merely on activities as the mediator of value rather than on the product itself. A focus is on the performance (function)[14] the system gives to the users during a period of time (McAloone 2011).

"... In place of the product alone, the activities and knowledge associated with the use of the product are increasingly perceived to be augmenting the design object ..."

As the above statement indicates, the product can be seen as augmented in time, through an extended stakeholder gallery, and a set of new relations, where co-development and co-operation is a necessity. Therefore, the product and the life phases must be carefully designed to meet the needs of the user but also all the new involved stakeholders (e.g. a service network).

5.4.1 PSS Conceptualisation Framework

The actual product development activity for PSS may not differ from the traditional product development process itself (Tan 2010; Matzen 2009). Many applied processes have been transferred directly from other disciplines, such as engineering design (Tomiyama 2001; Roy and Cheruvu 2009) and service design (Morelli 2003). The distinction is within the tools and approaches used within each stage, the combination of these (Finken et al. 2013), and the understanding of how different stakeholders

[13] The PSS dimensions are still under convergence, and no final set of dimension has been agreed upon. Refer to Chapter 2.2 for a discussion of this.
[14] "The functional unit is the reference point for designing a PSS and is described as the quantified performance expectation of the product over a given usage period and frequency ..."

are involved during the process (Mougaard et al. 2012; Manzini et al. 2004). In the process of PSS conceptualisation, the various PSS dimensions must be revisited and coherently designed, in order to mutually support each other (Tan 2010; Matzen 2009). A PSS concept has been created when all of the PSS dimensions have been described (Tan 2010). Different frameworks have been introduced by various scholars, representing different approaches for what and how to include the different PSS perspectives towards a holistic PSS conceptualisation framework. In Mont's framework (Mont 2004) and its three larger elements: PSS feasibility; Institutional framework; and the PSS elements, Figure 30, the main focus for this model is the evaluation phase of PSS development.

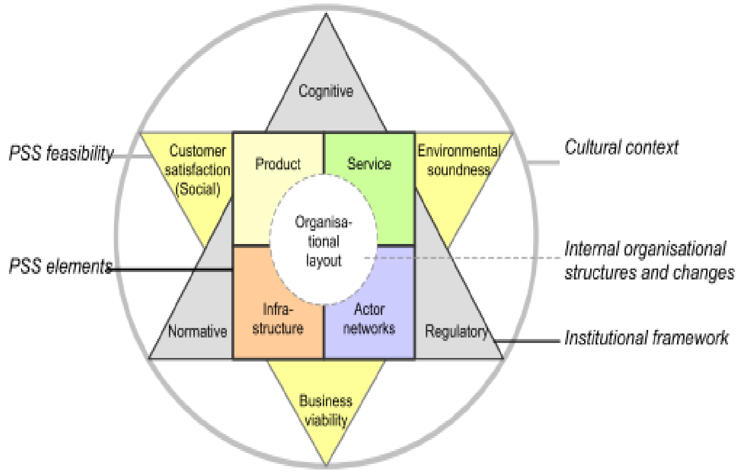


Figure 30: PSS framework for evaluation by Mont (2004)

The framework by Tukker (Figure 31) does not explicitly describe the different PSS dimensions, but instead details subcategories of a PSS, with its main focus on the payment structure. This framework is frequently used to distinguish between the different types of PSS, e.g. product oriented or result oriented.

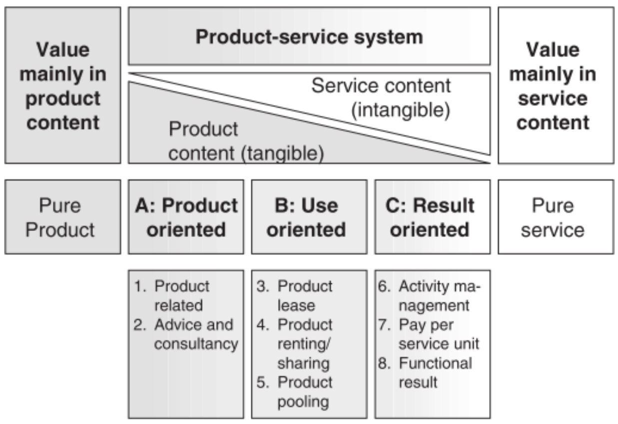


Figure 31: Eight PSS models (Tukker 2004)

Manzini et al. (2004) present a framework for conceptualising Solution Oriented Partnerships (SOPs), which are described as a "*strategic partnership sharing a common vision about how to deliver a conceived solution idea*". The framework is built like a matrix, with three dimensions: *partners; context;* and *solutions*, with the aim to develop a 'solution platform' by exploration and development of each of the three dimensions. The solution platform supports the focus for PSS development, which is not a specific product and service but a 'platform of solutions', upon which the customer and partners can reach the defined PSS solution through different approaches.

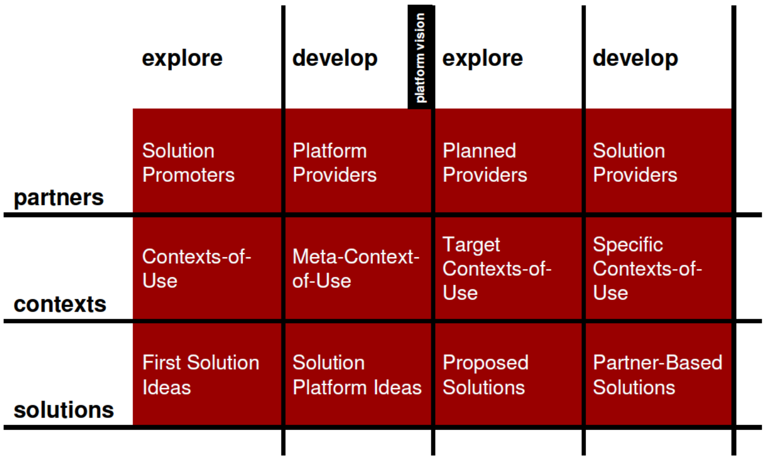


Figure 32: Framework for Solution Oriented Partnerships, by Manzini et al. (2004)

The framework is not a process framework, where sequential steps must be taken, although it suggests tools to be used in each of the twelve action areas. In this way it acts as a reference framework, where tools in coherence could be developed and presented. Furthermore, the framework is not a conceptual framework, although it can be compared to the PSS conceptualisation framework Figure 33, covering the PSS dimensions, lacking only offering life cycle thinking.

The *PSS concept model* presented by Matzen (2009) contains three distinct but interconnected domains: i) Artefact system; ii) Activity system; and iii) Actor network that is built on the Domain Theory (Andreasen (2011), much similar to the framework by (Tan 2010) a *Meta-model for PSS conceptualisation*, presenting a PSS concept to constist of three dimensions: i) Customer activities; ii) actor network; iii) Product life phase system; and iv) with a fourth element defined as the effect (value proposition) of the system. Later, Tan presents this framework in a new form a *PSS Conceptualisation methodology,* where a set of design stages are connected. The framework for PSS concept evaluation and development by Mont (2004),contains four distinct elements: i) product; ii) service; iii) infrastructure; and iv) actor networks.

The framework used in this research project was developed during the PROTEUS consortium (Finken et al. 2013) and with a basis in the continuation of the work carried out by Tan (2010) and Matzen (2009).

The final framework consists of four dimensions: i) Offering Life Cycle; ii) Value Proposition; iii) Ecosystem; and iv) User Activity Cycle. This framework connects multiple dimensions of the previous frameworks. This is also discussed in the industrial foundation of this thesis, but shortly, to summarise the link to previous work, the Offering Life Cycle corresponds to; 'Artefact system' and 'Activity System', and 'product' and 'service' element, the term offering life cycle is to put attention to the continues support of the product or the activity, which can cross multiple product life cycle and also cross activity cycles between users. The second dimension, 'User Activity Cycle', is in the mix of 'Service' (Mont), 'Activity system' (Matzen), and 'Customer Activities' (Tan), with distinct focus on the user perspective on the PSS system, also following a continuous life cycle and which can shift between users and customers. This is the least in focus in the framework from Mont. The 'Ecosystem' corresponds to the 'Actor Network' (Tan, Detlef, and Mont) and the 'Infrastructure' (Mont), where also the focus that Mont puts on 'PSS Feasibility', 'Institutional Framework', is an integrated part of the ecosystem dimension within this research project.

The framework can be described as a 'methodological reference model for PSS development' (see Figure 33), as it combines: i) four fundamental PSS dimensions: ecosystem, Value proposition, offering life cycle and user activity cycle; with ii) four development phases: analysis, definition, conceptualisation and implementation/evaluation. The dimensions and phases, in combination, 'interact' and come to play through an iterative process of PSS conceptualisation between the different phases and between the different dimensions. There is *no right way* through the framework, though an out-side-in approach is suitable (Finken et al. 2013) if no PSS solution exists already.

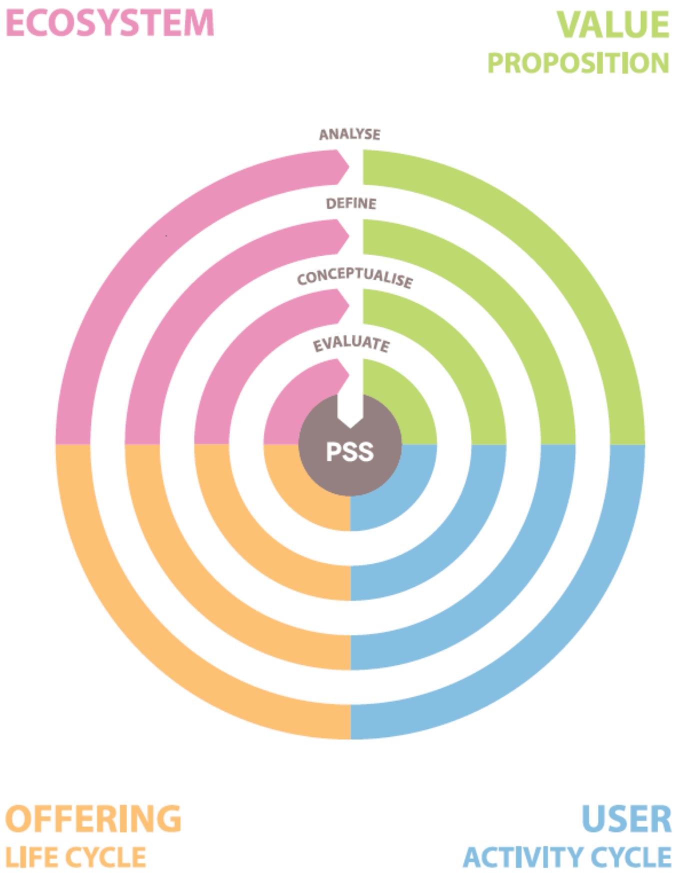


Figure 33: PSS conceptualisation reference framework

5.4.2 PSS conceptualisation definition

A few definitions and reflections will be presented in this section to bring a context to the framework and tools developed in this research project.

Conceptualisation is a creative, context-led process, involving a sequence of activities, with a set of tools or methods, applied in a structured manner. From the PROTEUS project, PSS conceptualisation is recommended to be carried out through iteration of the four PSS development phases simultaneously, structured according to the four PSS dimensions (Finken et al. 2013). The perspectives of each dimension can be approached individually for analysis but must be reconfigured and adapted by collective synthesis (Tan 2010, 196). Therefore conceptualisation activity must cover one or more of the PSS dimensions. The process of conceptualisation allows the development team to generate multiple PSS concepts, where products and services are integrated in an early phase of development, and to generate and form an overview of these concepts (Tan 2010, 197). Visualisation and representation techniques are essential to be able to communicate ideas within the team at an early conceptualisation stage (Krucken and Meroni 2006; Manzini et al. 2004;

Morelli and Tollestrup 2009; Storga et al. 2013). This is important for many reasons, including:

- The design object is not only tangible but represents different intangible and complex elements detailed by the four PSS dimensions (Mont 2004).
- PSS development is cross-disciplinary involving competencies and capabilities broadly within and external to the company (Manzini et al. 2004; Davies 2004). This is why a focus must be put on boundary objects.
- Being able to model PSS concepts while they are still abstract is fundamental (Tan 2010, 195), and this keeps the solution space open (Van der Horst et al. 1999).

Within the field of PSS, conceptualisation becomes naturally linked to new business development, which puts a demand on the business strategy, matching development approaches and the actual value proposition conceptualised. The PSS concept is at times on an abstract level, where the concept must be matched with the resources and capabilities present within the company. PSS strategies are an integral part of the value proposition development, where the company needs to consider channels and external stakeholders' involvement in the business (Foote et al. 2001; Davies et al. 2006), bringing the conceptualisation activity very close to network development, e.g. with examples by Matthyssens and Vandenbempt (2008) on offering tailored systems (integral position focus on product); and process management (integral with customer process focus) or turnkey solutions (a mix of both). Here internal development, partnering or acquisition strategies can be the solution for the lack of existing resources within the organisation (Davies et al. 2006). Balancing between product, service and business development is a challenge within PSS conceptualisation, for which reason a focus is necessary, on tools and participants with the right competencies and knowledge foundation. There must be continuous iteration between 'PSS conceptualisation' activities and 'PSS development' activities, as these needs to be constantly aligned.

The starting point for conceptualisation is the value proposition (Tan 2010) which also serves as a point of reference during conceptualisation. Multiple PSS designs can be made to meet one value proposition; e.g. a transport solution with guaranteed cost per km can be solved by different products, i.e. trucks (e.g. function), and different service constellations and agreements. Furthermore, the network configuration for establishing the correct service network, customer involvement, and internal organisational structures are manifold. A systematic approach to generate and consider alternative variations of the different PSS characteristics has been developed by (Tan 2010), where a set of seven strategic PSS characteristics and examples of variations of these constitutes a morphological scheme for PSS concept creation. Furthermore, another framework for PSS business development integrates two perspectives: i) the actual value proposition conceptualisation; together with ii) the business strategies. It is argued that this can open the solution space by identifying the service-oriented degrees of freedom in the design activity and thereby create new PSS concepts.

Based on the above considerations, the working definition for this research project, of a PSS conceptualisation activity was defined as follows:

- **#1: An activity (one or multiple) includes the perspectives of multiple design objects (PSS dimensions) and iterates between these, as well as the different PSS development stages. PSS conceptualisation makes use of a variety of design tools to open the PSS solution space, for the introduction of novel and sustainable PSS solutions.**

Furthermore, the PSS conceptualisation can be said to have the aim:

- *"... This phase should result in a number of PSS concepts, ideally described to the same level of detail, prototyped to an extent where they can be tested, and prioritised by means of a systematic selection process ..."*

5.5 PSS offerings typology as a catalyst to a toolbox for PSS

This section seeks to answer following research question:

RQ2: How can a PSS offerings typology support conceptualisation of new PSS solutions?

The PSS offerings typology can take many forms, if it is to be used by industry practitioners. Its main aim within this research project was to: *act as a 'boundary object' strengthening the understanding of value propositions of PSS strategies, during a collective activity.*

Boundary objects are described to allow coordination without needing consensus, by supporting the individual understanding and within the context of the group (Star and Griesemer 1999). This way, boundary objects act as entities which can bring groups to collaborate on a common task. A brief return to the models developed for conceptualisation by Tan (2010), the i) 'service strategy model' and ii) 'PSS morphology', with its strategic characteristics and its variations, was used as a point of departure.

The PSS morphology was described as follows:

"... *By considering alternative variations of the strategic characteristics new PSS solutions would become apparent for the PSS developer – the morphology gives an overview of some of the most common PSS development possibilities for manufacturing firms ...*" (Tan 2010).

Within a PSS strategy, all the characteristics must be detailed to describe the PSS business model and the development strategies possible. In the process of developing the PSS offering typology, it was identified that a single offering was commonly a cluster of different characteristics, described by minimum two of the strategic characteristics within the morphology, often with a basis in:

- Responsibility or management of product life phase.
- Support of management of product life phase.

Examples included *Maintenance & operation* and *Installation & training*. Systematically choosing between alternatives strategic characteristics is also a way to distinguish between a PSS strategy and a 'PSS-offering' – offerings are viewed within this project as fragments/elements of the PSS strategy.

In the development of normative methods for industry practitioners, the notion of overview and visualisations was adopted. Visualisations can be described as representations, and the representations' (information visualisation) core cognitive benefit is argued to act as a boundary object of references – a temporary storage area for human cognitive processes (Hornbæk and Hertzum 2011). This matches the older notion of a design model by (Buur and Andreasen 1989), where the design model is seen to have different operations, with aims such as: define, generate, describe, verify, evaluate, specify and arrange. These cognitive processes can be seen as learning processes, in which multiple and diverse people can enter a conversation using these 'boundary objects' (Star and Griesemer 1999). Within engineering design, Buur and Andreasen (1989) argue that design models are used as abstract representations of design objects and their propositions allowing the designer to describe:

- Structural characteristics; and
- Stimulate, analyse, and evaluate their behavioural properties before actual implementation.

Design models and visualisations can be viewed as having shared aims. Hornbæk and Hertzum (2011) describe visuals as a way to amplify cognition by:

- Increasing memory and processing resources available.
- Reducing search for information.

- Enhancing the recognition of patterns.
- Enabling perceptual inference operations.
- Using perceptual attention mechanism for monitoring.
- Encoding information in a manipulable medium.

Hornbæk and Hertzum (2011) developed a notion of overview and argued this to be a main goal of a representation. Based on a large study of 3,945 papers,[15] they developed the following four elements to be descriptive of any overview:

- Overview is an awareness of [an aspect] of an information space.
- Acquired by [a process] [at a time].
- Useful for [a task] with [an outcome].
- And provided by a [view- transformed] [visualisation].

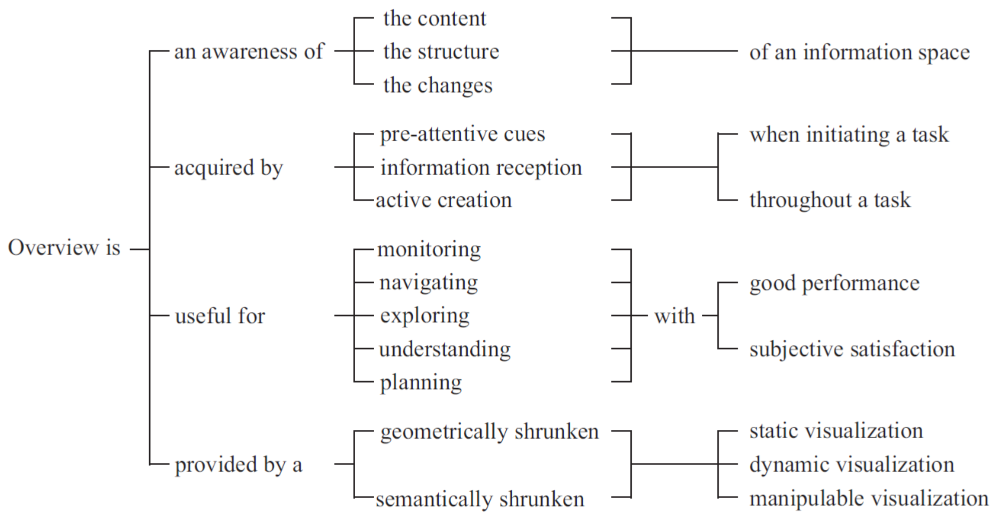


Figure 34: A taxonomic model of 'overview' (Hornbæk and Hertzum 2011)

Figure 34 presents a taxonomic model of overview, expanding the four elements of overview, where the *useful for*, can be compared to Buur and Andreasen (1989) list of *operations* above. It can be argued that the taxonomic model of overview is more suitable today, because it thoroughly represents the active part of the activity overview.

[15] They have conducted a large literature study within the field of information visualization. They selected three journals and two conference proceedings. The review was during a nine year period (2000-2009) for a total of 3945 papers. From these, 99 had overview in the title or abstract and 60 papers had overview as the main topic of the paper.

Furthermore, methods can be understood as mental tools, which can bring the designer a structure to thinking (Daalhuizen 2014).

Definition of a method can be as follows:

"... a goal-oriented rationalisation or imagination of designers' work in the form of a standardised work description ..." (Daalhuizen 2014, 34)

To add to the description of PSS conceptualisation #1, mentioned previously:

- **#2: PSS Conceptualisation must use boundary objects, with representations and visualisations during the process as these are vital for capturing PSS concept elements in an abstract form, thus allowing innovative solutions.**

The notion of a PSS concept element (PSS CE), are introduced to emphathise the fact that the process of a conceptualisation activity, brings PSS concept fragments that represents parts of a PSS concept, and when brought together they form a PSS solution.

These two propositions guided the development of the tools developed in this research project. Using the notion of overview discussed above, the two models developed in this research project are described.

Table 19: The two PSS tools developed in the prescriptive study 1.1, detailed by using the notion of overview.

	OFFERING CARDS	PSS CONFIGURATION TOOL
An awareness of	[the content] – the information space of [existing offerings within the maritime industry]	[the content, structure and changes] – the information space of [existing offerings within the maritime industry]
Acquired by	[pre-attentive cues, and active creation] during [PSS development phases – synthesis & conceptualisation] – throughout a task	[pre-attentive cues, and active creation] during [PSS development phases – synthesis & conceptualisation] – throughout a task
Useful for	Exploring, understanding, planning - > Subjective satisfaction	Exploring and planning - > good performance
Provided by	Semantically shrunken – static visualisation	Geometrically shrunken – dynamic visualisation

Two PSS conceptualisation tools were developed to make the PSS offering typology into normative PSS tools for industry practitioners to use intuitively. The meta-data captured in the PSS offering typology consisted of the following:

- A set of 48 unique offerings – each with its own unique name
- A description of each offering
- A short focus line – summary of each
- Each offering was assigned an icon
- All offerings were divided within five clusters of offerings

5.5.1 PSS tool 1: PSS offerings cards

Building compilations of methods, questions, etc. to prompt a team, in a creative process or design and product development activity, with: i) inspiration; ii) an obstruction; or iii) a hint of how to continue has been developed by many. Books containing collections of methods include examples like *Universal Methods of Design* (Martin and Hanington (2012) and *Engineering Design Methods* (Cross (2000). The international design and consultancy firm IDEO launched a free-of-charge online downloadable book called *The Design Kit to Human Centred Design* (*Human-Centered Design toolkit* 2009). So-called *inspiration cards* are emerging as an approach to bring methods very close to the design activity, using a tactile and strong visual representation method. An example of this is the IDEO method cards, which were created according to a set of categories following the design stages: Learn – Look – Ask – Try. The result was a set of methods for each category, each with its own focus on understanding the user in the design process. Similarly Roger Von Oech developed the Creative Whack Pack (Von Oech 1990), which supports any brainstorm by introducing real-world examples (Figure 35).

With inspiration in the look and the tactile properties of inspiration cards, a deck of *PSS offerings cards* was developed (Figure 35). The cards were developed to contain:

- Title and description of the offering.
- Easy recognition of single offering via icon and its affiliation to a service strategy through a colour code.
- Contain overview cards—with all icons belonging to a single service strategy.
- A set of game rules.

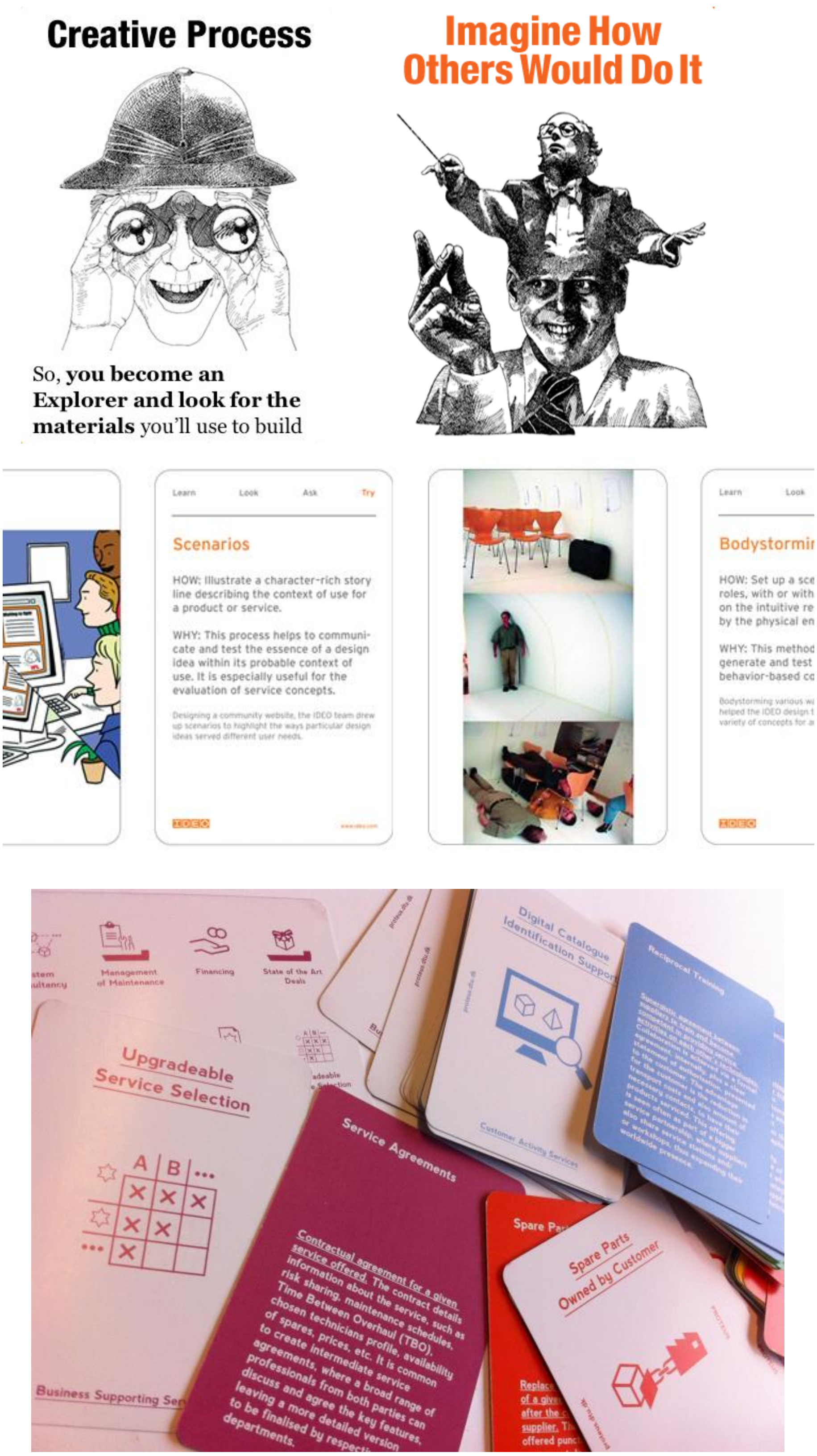


Figure 35:(Top): Pictures of existing creativity cards 'Wack Pack' from Roger Von Oech. (Middle): IDEO methods cards. (Bottom): Picture of the PSS offerings cards—developed and produced in this research project

A tool such as the PSS offerings cards can have multiple activities and outcomes. Table 20 presents a set of possible use scenarios. This tool aims to inspire and support conceptualisation of PSS solutions in a tangible way and to initiate and facilitate a discussion on PSS offerings in the companies. Each card represents an offering, with its full explanation found on the back side. All the offerings are categorised according to the PSS development strategies, and for each strategy, a 'group card' presents all offerings falling under each development strategy category—also supported by a colour code.

Table 20: Use scenarios for the PSS Tool, 'PSS offering cards'

Name	Description of use scenarios
Flicking	Flicking through the cards give an understanding of the current industry level of offerings.
Mapping	Mapping the current offerings within a company, based on i) markets ii) business areas.
Benchmarking	Benchmarking by mapping the offerings of a competitor
Blueprinting	"Service blueprinting" by mapping offerings following the journey of the customer, connecting details of the stakeholders connected
Obstruction	Obstructions to force developers to integrate a set of e.g. 2 services within each new development project.
Gain knowledge	Gain knowledge in a team, challenge one another on each card.
Clustering	Clustering to conceptualise new PSS offerings packages.
Challenge	Map the offerings – what is not currently present in the company is the capabilities present, or is new needed to
Abruption	Within a conceptualisation activity, use the services as abruption.

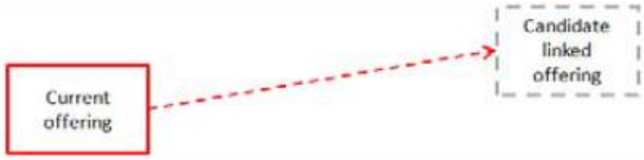
5.5.2 PSS tool 2: PSS configurator

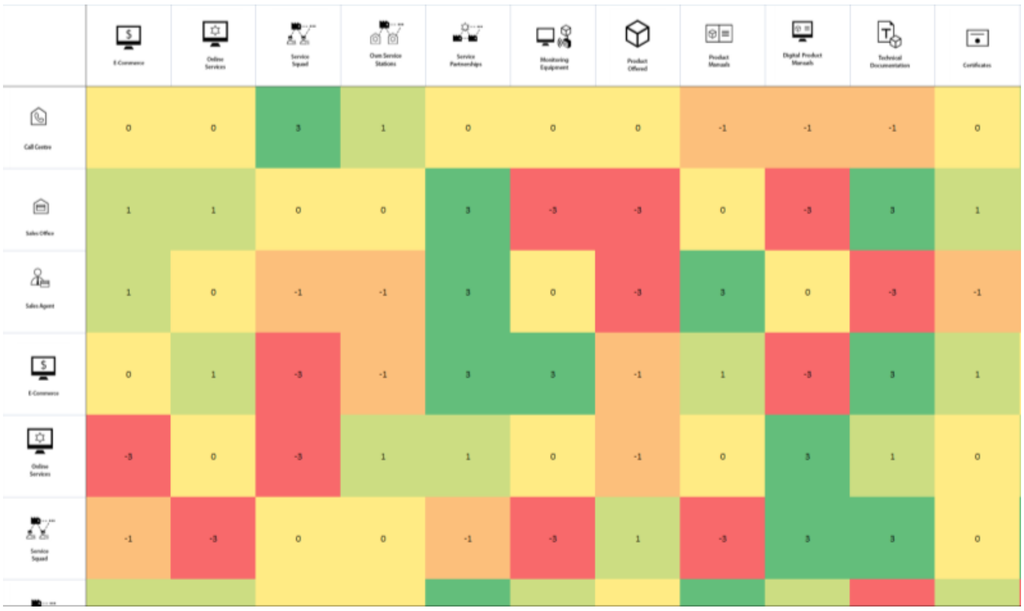
This tool is a high-fidelity prototype of an online software, to inspire the planning and design of PSS solutions (see a screen dump in Figure 37). Through multiple iterations and versions, the configurator was developed to include the following functionality. The 'logic' behind the configurator is built by mapping the affinities between the 48 PSS offerings + 7 PSS channels, identified from the ten participating companies in the research project. In total this gives a set of 3,658 combinations. For each of the relations between the offerings a value was given, according to a coding scheme that represented the type and strength of affinity of each offering pair under consideration Table 22. The affinity mapping and the development of the tool was carried out in collaboration between the PROTEUS project staff from DTU, an external application software firm—Rassvet (www.rassvet.dk) and the technical consultancy partner in the PROTEUS consortium, IPU. The coding mechanism for mapping the affinities can be seen in Table 22 and in Figure 36, where an extract of the actual affinity mapping behind the PSS configurator can be seen.

Table 21: Functions of the PSS configurator tool

Function	Description of function
Overview	Overview of all offerings; visualised by icon and title
Offering information	Information on every single offering: Moving the curser around the chart enlarges each square and its icon. More information is available by clicking on the letter 'i'. The offering description will appear in an enlarged square.
Configuration	Configuration of a PSS strategy – by selecting offering it will guide the developer by showing what its affinities are with the rest of the offerings, by indicating: - The selected offering (yellow – and blue full line) - Required (yellow – and blue dotted line) - Recommended (fainted grey) - Available (white) - Not recommended (white transparent)
Added information on configuration feasibility	Of the selected offerings it will be visualised how many selected and required offerings the selection will need to be fully functioning.
Offering package support of User Activity Cycle	Of the selected offerings – a pie chart – will give an overview of where in the User Activity Cycle the configured PSS is represented.
Continuous feedback	Also the split in the User Activity Cycle is presented in percentages at the bottom bar.
Report and share	Report function: allows the developer to save the configuration and email a link – and its possible to return and continue work on the configuration.

Table 22: Coding mechanism used for mapping the affinities

#	Description of mechanism	Illustration
+3	Positive affinity – with a strong opportunity for PSS related business creation	
1	Enabling affinity – this offering is an enabling offering for other offerings (opposite precursor)	
0	Neutral – has no relation to the current offering	
-1	Precursor activity – an offering which must be in place before the current offering can be considered	



	E-Commerce	Online Services	Service Squad	Own Service Stations	Service Partnerships	Monitoring Equipment	Product Offered	Product Manuals	Digital Product Manuals	Technical Documentation	Certificates
Call Centre	0	0	3	1	0	0	0	-1	-1	-1	0
Sales Office	1	1	0	0	3	-3	-3	0	-3	3	1
Sales Agent	1	0	-1	-1	3	0	-3	3	0	-3	-1
E-Commerce	0	1	-3	-1	3	3	-1	1	-3	3	1
Online Services	-3	0	-3	1	1	0	-1	0	3	1	0
Service Squad	-1	-3	0	0	-1	-3	1	-3	3	3	0

Figure 36: An extract of the actual affinity mapping behind the PSS configurator

5.5.3 The limitations of the tools and the approach

The limitations of the tool were within its representations of the affinities. The configurator does not allow for a point of departure in one offering and one version of a related required offering and optional; instead it shows all possibilities. In this way, the configurator will expand the solution space, rather than narrow it. Nevertheless, the configurator is an interesting alternative to the PSS offerings cards, as a way of making links between the charted PSS offerings.

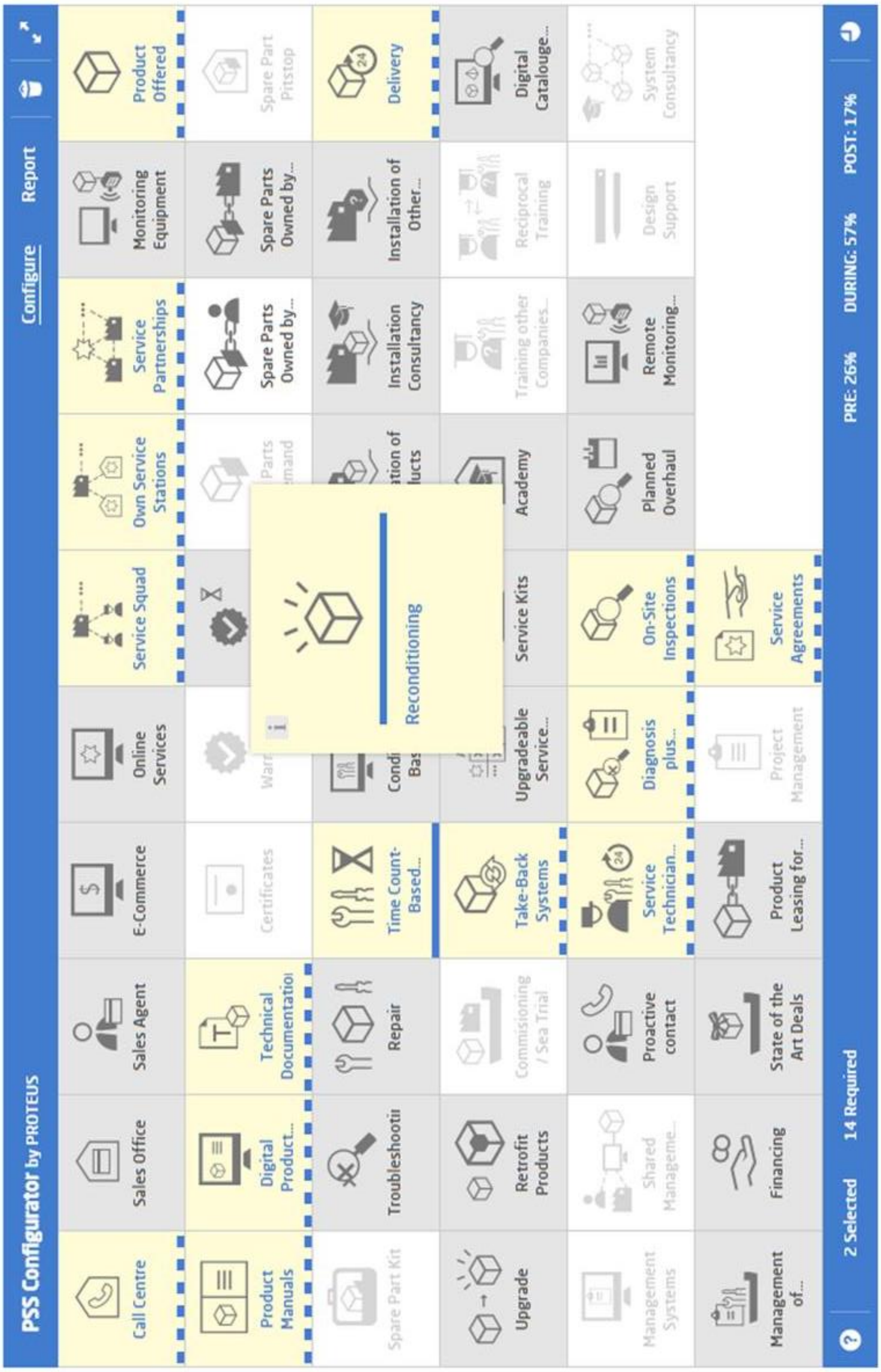


Figure 37: Screen dump of the prototype of the PSS configurator

5.6 Summary

This chapter has investigated Research Question 1: *through what terms and models can PSS offerings be described in order to support their successful synthesis*? The chapter reflects on a comprehensive descriptive study, presenting a cross-disciplinary literature review, which elaborates on many approaches towards the description of PSS offerings, including lists, matrices, transitioning frameworks, continuums, meta-clusters, categories, typologies, industry examples, and many more. The literature review shows that many of the existing frameworks are descriptive and do not bring normative methods for industry practitioners, also many of the typologies have been developed based on theoretical studies, and seldom on cross-case studies. Multiple researchers point to the need for convergence in PSS research in the terminology used in the field, particularly with a focus on the PSS offerings.

Many transitioning frameworks have been identified, which represent step-by-step processes or product-to-service continuums. These are an integration of service categories and PSS strategies – or so-called PSS archetypes, which provide a context within which to position and present the PSS offerings. One of these frameworks has been chosen as point of departure for further development of an industry specific typology.

By using all ten companies from the innovation consortium PROTEUS as single cases, has made it possible to build an industry-specific PSS offering typology. The typology is presented by describing all the offerings in detail, one-by–one. A total of 48 offerings, with examples such as: condition-based monitoring; trouble shooting; and take-back systems. The charting clearly indicates that the companies of PROTEUS have moved their respective businesses closer to servicing the customer, away from a traditional sole focus on the product. The strongest service strategy identified among the ten companies was *customer activity services*.

Furthermore the PSS offering typology has been presented and evaluated by using it as a analysis platform for the industry/companies. The synthesis of the industry level of servitisation (the PROTEUS companies) was achieved by describing each of the identified offerings, using the companies to illustrate the application of the typology, supported by integrating the literature review to elaborate on the findings and further describe the background for the typology. This underlines the many perspectives needed, when moving towards a more service-oriented business.

The second part of the chapter addressed Research Question 2: *How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?* The chapter started by diving into PSS conceptualisation, by elaborating on what defines PSS conceptualisation.

The design object changes when conceptualising PSS, compared to regular engineering design and product development. The process can be said to be similar, containing the same design phases, but the choice of tools used within each phase varies, from product- to PSS development. The PSS Conceptualisation Framework developed during the PROTEUS consortium has been presented, consisting of the four PSS dimensions: ecosystem; value proposition; offering life cycle; and user activity cycle, plus the four PSS development stages: analyse; define; conceptualise; and evaluate. The chapter then presents the development of two PSS tools, by use of the 'notion of overview'. A taxonomic model of overview is used to guide the development and the presentation of the two PSS tools. The PSS offering typology has been transformed into a set of inspiration and creativity cards, containing all 48 offerings and 7 sales channels identified in the descriptive study. The second tool is a software-based online configuration tool, which supports the PSS developer in a systematic process of selecting a PSS offering package, by use of an in-built affinity logic. The chapter closes with a list of use scenarios for both tools.

6.

PSS ecosystem conceptualis-ation

6. PSS ecosystem conceptualisation

This chapter unfolds the prescriptive study 1.2 which is based on the theoretical study conducted to create a systematic approach for: i) describing and synthesising the ecosystem of a PSS; and ii) conceptualisation of a PSS, using a network approach. A set of PSS ecosystem characteristics is presented and a new PSS tool, 'PEC' and a PSS network conceptualisation approach. This chapter seeks to answer:

RQ3: How can a PSS conceptualisation activity allow an inherent network approach for co-development of the PSS-design?

The value creation process within PSS spans multiple stakeholders, crossing departments and company borders. Involving multiple stakeholders is manifested through that the PSS is augmented in the time domain, as the value is merely created with base in relational activities and not transactional activities. The sale of a product is replaced with sale of the product's performance in the advanced PSS. The sale of a product can also be aggregated with a service package, where parts of the customer activities or business processes are taken over by the supplier or a network of suppliers. Both offerings require a changed approach between the stakeholders and their position in the PSS ecosystem, with new forms of organisation like '*companies as flexible networks*' (Manzini 1999). This chapter focuses on systematic approaches for describing and conceptualising PSS with point of departure in the changed, or possibilities for a changed, relationship among the stakeholders within the ecosystem.

6.1 A network-based PSS conceptualisation activity

This section will present i) the criteria the development of the support is based upon; ii) the actual development approach; iii) description of the support, a new PSS tool; and iv) a description of the intended use. Finally, it will describe what part of the Support will be validated.

What we have seen in PSS literature is that the structural characteristic of PSS and the behavioural properties of PSS have been discussed and presented in the work by (Tan 2010). The properties are suggested to serve as inspiration while judging the relationship between the supplier and the customer as: *Are the new properties attractive enough in the relationship to ensure that the total perceived benefits are greater than the total sacrifices?* (Tan 2010, 172). How is it possible to be able to describe the network at such a level that the true importance of this will be brought to the PSS designer? And can design opportunities of new relationships within the PSS ecosystem be found?

The aim for the support is:

- **#3: A tool that allow the analysis and conceptualisation of the PSS ecosystem is needed, which can allow all stakeholders taking part in the system to collaborate. This is done at a level through which as many as possible aspects of the PSS ecosystem will be uncovered - this will enable the designer to integrate and exploit the network perspectives to bring novel PSS solutions.**

Based on the findings from the literature study, the support should aim to take into account the following facets:

- Include an approach to bring an overview of the stakeholders in the PSS ecosystem.
- The conceptualisation activity should facilitate collaboration between multiple stakeholders.
- Be applicable in a context where different departments within and external to the organisation take part in the conceptualisation.
- Support effective communication across different stakeholder groups concerning competence field and level.
- Allow for the ecosystem representation to include a multiple stakeholder view.
- Build a terminology to detail relations within the PSS ecosystem. Characteristics have yet not been agreed upon by scholars.
- Take into account the complexity the PSS approach brings to the development activity.
- *Leverage on the combination of network and PSS theory*.
- *Use a case study for validation where multiple stakeholders collaborate in conceptualising new PSS solutions*.

6.1.1 The development of the PSS ecosystem characteristics

The literature study was designed according to Bloom's taxonomy (Flick 2014) of the cognitive domain, where analysis and synthesis was dominant. The method for the literature study phase with knowledge comprehension was conducted through dialogue with fellow researchers. This resulted in an interpretation and extrapolation, simultaneously building a structure and pattern of the different theoretical constructs, which was mapped in a large spreadsheet. The literature study iterated and continued until similar results appeared multiple times for a construct, phenomenon, theme, or author. The review was carried out by using affinity diagrams, where affinity sets were developed and redeveloped continuously. For this process particularly, the method of iterative exploration was used, resulting in six key characteristics. The use of colour codes and numbering made one set less likely to dissolve into a new set, and the final groupings into the six PSS ecosystem characteristics were named at the very end.

Within the research project, a characteristic can be understood as:

- A feature or a quality of a person, place or thing and serving to identify them (Oxford online dictionary).
- A special quality or trait that makes a person, thing, or group different from others (http://www.merriam-ebster.com/dictionary/characteristic).

6.1.2 The PEC – PSS Ecosystem characteristics

The following characteristics present the key findings in this research project's prescriptive study 1.2. These characteristics have been evaluated through a comparative case study, which is presented in Chapter 7. The characteristics do not hold a scale or a set of variations, but shall be seen as characteristics vital to the understanding and evaluation of the PSS ecosystem.

- Between stakeholders: (Who/Stakeholders)
- Relationship intensity: (How/Intensity)
- Goal of the relationship: (Why/Goal)
- Value creation: (What/Aim)
- Time domain: stability (when/Time)
- Front and back: (where)

Table 23: A set of PSS ecosystem characteristics, main finding from the prescriptive study 1.2

Characteristic	Description
Between stakeholders [WHO]	A PSS is comprised of networks of stakeholders internally and externally to the firm, which in combinations and through interactions constitute the surroundings of the PSS. The stakeholders or the activities of these can constitute the nodes in a stakeholder network. Depending on what level the stakeholders will be detailed, it will constitute the resolution for the network.
Relationship intensity [HOW]	Every relationship is characterised by a link, a specific tie between the stakeholders, through which a unique value, a "deliverable," flows. The intensity can be detailed by whether it is transactional, relational, or a mix of both, elaborated on by the activities the relationships that exist within i) coordination, ii) cooperation, iii) collaboration.
Goal of the relationship [WHY]	A relation will always have a purpose or a goal, which brings a context to the relationship. These goals can be staying competitive, increasing marketing, new competitors, exploring new markets, sharing risk. A single relationship goal can vary from the overall network goal.
Value creation [WHAT]	Each link in the network holds a certain value to the system through supporting one or more of the following categories:

	product, product use, product life, customer support, business support. Defines what the links between the stakeholders are whether this is tangible or intangible.
Time domain [WHEN]	As a PSS unfolds over time, the relationship within the network has different time appearances. Some will be simultaneous, and others will be on and off. It can be short-term, long-term, and some relations are only temporarily. It can take place in any of the activities connected to the two life cycles of the product or the customer.
Front and back-office [WHERE]	As a PSS moves the boundaries between customer and supplier, or others stakeholders within the network, distinguishing front- and back-office activities, supports identification of whether the activity/relationship is directly or indirectly perceived by the customer, or other stakeholders.

6.1.3 Between stakeholders

In terms of how the stakeholders are linked together, a PSS ecosystem is characterised by: i) who takes part in the system; ii) the roles and responsibilities of the involved stakeholders; and iii) as the structure of the system. In a transition from a product-based to a performance-based PSS strategy, stakeholders are reconfigured and tied together in new intra- and inter-organisational structures, creating new roles and perhaps new stakeholders as carriers of the PSS. A stakeholder can be defined by the organisational dimension of culture, resources, capabilities, and the people related factors as e.g. trust and commitment, (Tan et al. 2009) in any given PSS these are elements of vital importance as e.g. the increase of responsibility towards the manufacturer instead of the user, relies on existence of trust and cost transparency. Resources and capabilities of each stakeholder support identification of its role or potential role in the ecosystem. Ecosystem relations can be defined by the activities of the stakeholders spanning local or global sites as this gives insight into, e.g., culture and infrastructure differences, which might bring challenges or potential benefits to the relationship or ecosystem. Another essential element is the stakeholder scaling, which sets the resolution of the stakeholder network in the ecosystem. Stakeholders can be described as a team, department, company, or sub-network. The abbreviations B2C (Business to Consumer) and B2B (Business to Business) are argued to be irrelevant as they indicate a sequential value chain structure, where the last chain is linked to the customer, user, or buyer, instead of an ecosystem where everyone is in the same 'business' acting collectively towards a joint value proposition.

Global Product Development describes a relationship across country borders linked together by development activities. Also, Integrated Product Development is used to describe a link between departments within a firm around a design task. Both of these are vital in PSS development as intra-organisational structure (e.g. between Sales, R&D

and service departments) needs to change. Furthermore, Global Product Development strategies might be needed if the different product life phases are split between stakeholders across the world. The collaborative product development put challenges on the stakeholders communication (Rönnbäck 2002), why it is important to integrate the right level of technology to support communication across the different companies participating. Rönnbäck (2002) argues that the use of inter-organisational IT (IOIS) at the right level is vital to implement, particular between a network compared to a dyad.

McAloone (2005) describes intra-organisational integration on four levels: organisational; business; system; and product, and claims that:

"... *Service-oriented product development requires vertical integration within the organisation, due to the fact that the PSS regards both core business decisions, product planning, product life cycle management and detailed product development expertise ...*"

Tan (2010) describes the need for integration as "... *The value of PSS approaches will only be realised if synergy or integration benefits can be achieved ...*" (Tan 2010, 87). This can be achieved by Intra-organisational i) Strategic integration of activities at different levels of decision making; ii) Functional integration of different units within the company and inter-organisationally; and iii) Logistic & Supply function integration. All of these also apply for inter-organisational relationships. Within a PSS, inter-organisational relationships become key for any successful PSS solution because the development and operation of the system involves, and is dependent on, many different stakeholders. These relationships are vital to management as competition and value is not based on a single firm but systems of firms and their interconnectedness. Within a PSS, the inter-organisational relations are in this research project argued to be managed and created, based on what Zajac and Olsen (1993) describes as joint value maximisation, instead of single firm cost minimisation.

Trans-function relationships are referred to in literature as Vertical relationships. Within result- or performance-based PSS, large parts of the customer's business is outsourced to the supplier (or PSS orchestrator), which has been doubt *Downstream Vertical Integration* (Wise and Baumgartner 1999). Trans-function relationships are between stakeholders of a particular industry or business. The relations can be found between all the different *product life phases (i.e. Value Chain Functions)* as: manufacturing, sales, distribution, logistic, and operation. PSS strategies often include Trans-function network integration, where, e.g., suppliers, distributors and service technicians are managed by a focal company, "often the main manufacturing company," through strategic alliance or partnerships. Trans-function integration is detailed through which extend a company own and has responsibilities for other companies' activities in the ecosystem, e.g. suppliers, sub-suppliers, customers and users. (Baines et al. 2011). Trans-functional expansion can also be referred to as Trans-Function acquisition, to achieve economies of scale, where similar companies are acquisitioned. High-install base products, products with long life, like the products in industries such as aerospace and transportation, also called high value capital equipment, have large potential for Trans-function integration as it holds large revenue possibilities through in-service support. Adopting such a position can be done through provision of installed base services (Oliva and Kallenberg 2003) offering service in the operating phase of a product. Many empirical PSS examples are cases where companies are moving closer to the end user (Baines et al. 2009a).

Same-function relationships, also commonly known as horizontal relationships, occur in the cases where complementary or competitive competencies or capabilities are linked. Same-function integration is a strategy to strengthen competitiveness of a company or ecosystem by increasing market shares, by added control of a market, via e.g. acquisition or buy out of competitors 'stealing market shares', with similar companies in the same industry or done by the launch of a new company with same offerings in a different name (Davies et al. 2006); this is an integration strategy with direct effect on economy of scale. Same-functional integration can be seen through package solutions, combining products and services for a specific activity, defined as e.g. *Technical application integration* through tailored systems (Matthyssens and Vandenbempt 2008). These relationships can also be established and managed between customers through e.g. a 'Purchase Same-Function Network'.

Leasing or pooling is a different service strategy of PSS, such as in the consumer market as with Laundromats and Car leasing systems (Mont 2004), where the users share the product. Between industrial companies, pooling can also be technical know-how.

Co-operative networks, are defined by a network of independent parties competing in one or more areas of their business, where creating and capturing value is done at the same time between the parties, combining competition and cooperation (Nalebuff and Brandenburger 1997). *"The basic philosophy underlying 'co-opetitive' business relationship is that all industrial management activities should aim for the establishment of mutually beneficial partnerships relations with other actors in the system, including competitors ..."* (Zineldin 2004, 1). Within this network, a mix is preferred of inter-organisational relations with both relations of trans-function and same-function, involving both competitors and/or complementors. Cooperative networks are characterised by the division of cooperative and competing activities between the parties (e.g. sharing of production or stock facilities and competing on product price and sales). It is common that the competitive activities are placed closer to the customer, and the collaborative/cooperative activities are placed with more distance to the customer (Bengtsson and Kock 2000), which therefore within a service-oriented activity of e.g. larger technical systems, like the ship, where multiple suppliers have overlapping service capabilities, increase the complexity of managing this division of cooperation and competition. These types of relationships can take different forms, such as: strategic alliances; partnerships; coalitions; joint ventures; franchises; research consortia; and many other forms of network organisations (Ring and Van de Ven 1994). A study made by Tan et al. (2007) describes a case study with a large international company, Steelcase, where the company, in the process of moving closer to a provider of integrated product and service offerings, acknowledges that they might need to make partnerships in both trans- and same-function relationships, forming a value network. They see that advancing in only trans-function relationships will not be sufficient.

The three different examples of relationship types above all focus on different constellations within the same industry. When defining relationships within the ecosystem of a PSS, relationships between unrelated industries, the so called *Intermarket networks* (Achrol 1997), are equally important. Intermarket networks were previously organised around major financial institutions, where today companies tend to be focused on technology. A PSS often crosses different industries, because what normally ties a company to an industry is the product, and within PSS the value proposition (e.g. performance solutions) includes stakeholders that are outside the product life phases (i.e. product chain) and therefore do not necessarily operate in the same industry. Another way to describe a relationship in the ecosystem is through *Opportunity networks* (Möller and Rajala 2007). This is in many ways similar to Intermarket networks, though this network is not necessarily across industries. The aim of this network is exploration of new ways of organising or doing business. Many different types of relationships can be mentioned here: service incubators, public-private-partnerships, i.e. triple helix, as for example research consortia.

6.1.4 Relationship intensity

The relationship intensity (interaction density) (Martinez et al. 2011b) between supplier and customer is used as a core characteristic to detail which type of PSS is offered (Matthyssens and Vandenbempt 2008; Martinez et al. 2010; Gaiardelli et al. 2013). The relationship intensity details the relationship by defining the 'degree of integration' and the type and strength of the bond in the relationship. The relationship intensity is often described by using two extremes: transactional and relational (Martinez et al. 2010). This view is simplistic, which is not necessarily the case in reality. These relationship are argued to exist in myriad variations, where long-term strategic alliances and short-term coalitions shall coexist

(Camarinha-Matos 2005). Looking at the servitisation continuum of Martinez et al. (2010), in illustrating the customer-supplier interface, a high level of servitisation has a high interface between customer and supplier through co-design solutions, where new interactions are created crossing product life phases. The same increase in intensity between stakeholders is also seen earlier in the life cycle phases, by, e.g., strong relationship between suppliers, via, e.g., system integration.

A Same-Function relationship between complimentary stakeholders can be formed by a *buyer/seller relationship* or a *risk-sharing partnership*. The intensity can be defined by looking at the management component of *planning* described by Lambert and Knemeyer (2004), where three different levels are presented: i) ad hoc; ii) regularly scheduled; or iii) both. The first mentioned relationship is therefore a low/medium level, and the later mentioned high level of intensity. This management component can also be compared to the financial structure, which in PSS is used as a key characteristic (Tukker 2004; Roy and Cheruvu 2009; Tan 2010). Moving from sales of a product towards sales of a performance changes the payment structure, from ad hoc, to planned payment by long-term contracts. Roy and Cheruvu (2009) describe six categories of contracts to support the risk management in long-term contracts like incentive contracts, time & materials, and fixed price contracts.

The two extreme relationships can be viewed as:

- Transactional = coordination / cooperation.
- Relational = collaboration.

The above comparison can be seen as a merger of Marketing and Network Literature. The intensity between stakeholders is within this research project argued to be an important characteristic to expand to other relationships besides just the one between supplier/customer. Furthermore, the view of transactional and relational needs elaboration, which can be done with the notion of coordination, cooperation, and collaboration (Camarinha-Matos and Afsarmanesh 2006).

- *Coordination* involves sharing of information and aligning activities, where each stakeholder has their own goal (e.g. lobbying together, service agreements, on-site inspections).
- *Cooperation* builds on top of coordination by sharing resources towards achieving common goals through joint planning (e.g. Supply Chain Management and different PSS offerings like Spare Part Exchange Programmes). Industry clusters can be in between cooperation and collaboration as they can share buyer/supplier relationships, common buyers, distribution channels, etc. at different degrees. They might even share common labour pools.

- *Collaboration* includes both elements of coordination and cooperation but includes also responsibility sharing, joint planning, implementing, and evaluation of the activities. The intensity can be described by looking at the type of collaboration (which means 'to work together' in Latin). Collaboration has a common aim, where coordination and cooperation can have separate aims for each participating stakeholder.

"... collaboration should result in creation of new and unique value propositions based on a unified approach to value creation ..." (Bititci et al. 2004, 1) p. 1.

If a collaborative relationship takes place between customer and supplier within manufacturing through a *risk-sharing partnership*, which is often seen in *total care offerings*, the preferable relationship across the different product life phases and its connected stakeholders would be collaborative or at least a high degree of cooperation. A study by (Cakkol 2013) showed that a PSS business strategy brought challenges to the sub-suppliers as information was not shared, decreasing the capabilities for the sub-suppliers to handle forecast and logistics of materials and parts. Offering integrated solutions through service strategies as supporting the product, and supporting the product life, requires a different degree of insight into the problems and applications of its customers and suppliers and sub-suppliers. This is why a greater degree of cooperation within the product life phases is necessary. This can be through implemented information systems, condition-monitoring systems, and service foresight activities, all of which can be done through transactional relationships but can be strengthened by a collaborative approach. Mergers and alliances serve basically the same goal, of combining complementary capabilities to reach shared strategic goals (Sawler 2005). Strategic alliances can be an example of a collaborative relationship as, e.g., MAN Truck & Bus and their MAN DIRECT programme, where risk and profit is shared with the dealers.

6.1.5 Goal and purpose

Relationships within a production system, or an operation system, can aim at maintaining a cost effective and reliable system, securing the right resources and parts at the right time. A goal of a relationships or a network can also be development activities to gain a market leading position or to develop a new market (e.g. standardisation networks, with the goal to be dominant companies within provision of and capabilities within a certain technology). Some relationships might exist only as access to other stakeholders. In these cases, the stakeholders act as accessors in the system. In network literature, some networks are defined by the existence of a goal, so-called *goal-oriented networks* (Möller and Svahn 2003) If this is the prime characteristic of the network, this is also an example where the relationship was named by its most prominent characteristic.

Resolution of the goal: Goals can be viewed on different levels, depending on the degree of resolution of the ecosystem; these can be defined by a single relationship between two stakeholders with focus on for example 'improved product utility' or between multiple stakeholders forming a sub-network within the ecosystem e.g. R&D activities aiming at a standardisation. Sub-network can to some extent also be seen as a stakeholder in itself, i.e. multiple stakeholders taking part in lobbying activities, pushing forward technology regulation or a certain need for a changed infrastructure. Furthermore, these different levels can be used to identify or form main goals and sub-goals. Multiple goals can exist within *one* relationship, like brand value, cost reduction, increased market share, transfer/exchange of goods, and new market segments. Also within a main goal, as e.g. lobbying activities, can be a sub-goal for a stakeholder e.g. manufacturer to be up-to-date with technology development, also indicating that the stakeholders e.g. within the same relationship might have different incentives for participating.

The goal of the relationship can be described through two views: i) perspectives; and ii) level of change, as described below.

PSS perspective: The goals of the relationships can be mirrored in the different PSS perspectives listed by (Tan 2010):

- *Design object*, with focus on the actual product and service offered, like reduction in emissions, minimising use, improved utility, etc.
- *Design process,* where focus is on the development process. Here the goal can be efficient information loops and integration of the user in development. Open Design can be focused on exploring new solutions through collective intelligence systems etc.
- *Business strategy*, here goals can be connected to mission and vision of the company, e.g. from product to performance strategies, increased market shares, new market segments, changes in KPI´s broadly in the organisation.

The goal of the relationship can be aimed at each of these different views/perspectives of a PSS. All three perspectives are necessary for a successful development of a PSS.

Level of change: Depending on the level of 'change' of each of the three above areas of PSS, the relationship can be described through what extent it will change the network and existing relationship. If the goal is to stay within the existing norms of the network, it can be referred to as the 'current network'. If the goal aims at changing the game rules in the market, it can be described as a 'Renewed network' (Möller and Rajala 2007). If the market does not exist yet and the goal is to reconfigure the whole business landscape, it is an 'emerging network', which brings to it larger risk and uncertainty. This is often referred to as radical innovation.

Distinguishing between these different goals is vital as often radical compared to incremental innovation requires different competences and resources (Tidd et al. 1997). Furthermore, these three different networks are important to consider and to be aware of as each requires different management mechanisms (Möller and Rajala 2007) (which is a current research topic in literature) Philips Lightning, for example, provides complete lighting installations by producing, installing, maintaining, monitoring, and paying for usage, take-back, and to the extent possible reuse or regenerate materials from the lighting system. In return, the customer pays a service charge over the entire period agreed upon. This changes their customer relations from commodity sales relations to a trusted service partner through a PSS.

6.1.6 Value Created & Value proposition

The Value Proposition is the overall value created within the ecosystem offered to the customer (e.g. 'guaranteed cost per km') through a performance agreement or a 'service agreement with flat-fee prices'. The value proposition can also be ownership of the product and guaranteed spares. Refer to Appendix A: Value proposition, for a larger compilations of different description of value proposition in connection to the PSS research field. As described earlier, this can roughly be defined through two outer poles of *Value based activities* where Relational-based activities refers to asset utilisation, Transactional-based activities refers to asset ownership. The activities can be defined and put in context by using the extended life cycle perspective the; product life cycle and the user activity cycle. If the relationship constitutes a development activity, it can be seen as *what* is being developed on three levels, component, product, and system (Ruiz and Maier 2012). Each level contains different strategies for co-development, where the design task increases in complexity moving towards system development. When defining the strategic characteristics of a PSS strategy (Tan 2010, 185) describes a PSS dimension as a degree of integration, where value is created based on i) core benefit alone; ii) benefits aggregated; and iii) multiple benefits integrated. When moving towards the last variation, 'benefits integrated', this corresponds to (Matthyssens and Vandenbempt 2008) 'tailored systems' and Turnkey solutions. As a 'system integrator', both of these correspond to the design activity of a system, but as a system integrator the company's business processes need to be aligned or integrated, thereby adding a complexity to the design task, moving from solely product development to integrated product and business development. As PSS is expanding the value proposition through augmenting it in time, the offering life cycle perspective and user activities are key to defining the value proposition as well. This is supported through the Service Strategy Framework (Tan 2010), as Product, Product Use services, Product Life Service, Customer support service, and business supporting services. The *what* can be any of the listed offerings in Chapter 5.

There are many different value propositions all influencing the type of relationship needed within the ecosystem for a successful PSS. Despite the overall value proposition of the ecosystem, this exists only due to the total set of relationship between all stakeholders in the ecosystem. Many business relationships exist with each their own value creation or co-creation activity. The value created can be viewed between single stakeholders, and refers to *what* is being delivered, links the two stakeholders or sub-group of stakeholders e.g. business units. Each relationship can be split in a variety of value strings (Allee 2000; Vargo and Lusch 2004). This means that multiple relationships can take place between the same stakeholders. The value created or the deliverables are temporarily and takes place at a certain point in time, compared to goals (roles) which continue over time. In this way, the value Proposition and Value Created can to a certain extent be measured and quantified. The actual link can have deliverables and exchanges, such as information, money, products, and 'value' (e.g. branding). ESCO (Energy Saving Companies) Siemens Building Technologies is another good example of functional sale and is often referred to as an energy saving company. They perform contracting services to provide customers with low-risk and self-financed energy saving solutions for large buildings and ships. The energy savings lead both to less money spent on energy consumption and lower CO_2 emissions.

6.1.7 The time domain

The value proposition is a promise of future value exchanges and co-creations (Stahel 2010) which within a PSS can be experienced during a defined period (e.g. within a contracted service period, or a proactive manufacture or service supplier supporting the customer anytime throughout the product's life cycle, before, during or after use). A PSS approach can be seen to exactly augment the product in time, expanding the value proposition in the time domain (McAloone and Andreasen 2002). The effect (the value creation) of a PSS can be found in the meetings, which is the actual context wherein the value is perceived by the user (Tan 2010). The meetings refer to a specific point in time where the product/system meets the user, defined by a product life phase and a user activity (Matzen and McAloone 2006). The perceived value of the customer will occur during a certain period of experiencing (perceiving) the system, compared to a product where the quality and properties can be more easily measured and evaluated at the point of purchase. The value proposition of a PSS, where performance is sold rather than the product, *is* a relational process (Vargo et al. 2008; Macdonald et al. 2011) also referred to as a 'solution-oriented partnerships' (Evans et al. 2007; Manzini et al. 2004) a long-term relationship with continuous interaction.

PSS is a user-centred design approach and a user-centred 'business model' here focus is on the customer's needs (which occurs in time and changes with time) and opens up after-sales opportunities for manufacturers, suppliers, and sub-suppliers, or whole new business strategies with new markets. Within a service oriented company, the value-proposition is created continuously over time, which demands maintenance, redesign, and *innovation,* setting a need for continuously redeveloping this through the 'network capability'. Within these new business approaches, the time domain of the PSS focuses on *when* relationships are needed and the *duration* (length) of these.

When: The offering life cycle and the user activity cycle is a sequence of phases or activities evolving in time, where a relationship can be centred around i) product life phases; ii) user activities; or iii) both of these. In trans-function collaboration, multiple life phases of the products can be taken over by a single manufacturer, characterised by these taking place a different points in time. In network literature, the time characteristic was used frequently to define a network type (e.g. 'opportunity networks' (Powell and Grodal 2006) that is contemporarily aligned and has a certain goal. Networks (e.g.: R&D, marketing network (Grönroos 1994), distribution, service-networks, etc.) also illustrate the point in time the relationship occurs, revealing in which 'product life phase' it occurs.

A success criterion within PSS is concentrated around the data feedback loop, from the operation and use of the system, to feed into New Product service development, preventive maintenance, and alignment of business decisions, within the whole ecosystem, spanning sub-suppliers, suppliers, manufacturers, and PSS orchestrators. This is characterised by being everything but linear, and this links the involved stakeholder together across many points in time.

Taking into account and viewing multiple customer activities pre, during, and post use has been a strategy for servitisation, finding new areas of adding value for the customer as suggested by Vandermerwe and Rada (1988). With the new approach of collaborative business models, this approach can be transferred to everyone within the system, e.g. the service operators (could be a partner company) to identify their business processes and identify areas of adding value to optimise their business, hereby making the whole ecosystem stronger. In the area of experience economy different method of supply concerns the time domain, when describing the move from commodities to experiences as; Stored in bulk (commodities), inventoried after production (goods), delivered on demand (services) and revealed over a duration (experiences) (Pine and Gilmore 1998), experience can be understood as performance or result based PSS. By Tan (2009) the time domain manifests by e.g. the characteristic 'Availability' with variations like; always available, available when needed (serial use) and available at certain times or places.

Duration: Besides the actual point in time the relationship occurs, (development or operation) a relationship can be characterised by its *duration*, also referred to its *stability* defining whether it is temporal or long-term. Matzen (2009) illustrates the relationship between supplier and customer through a 'partnership based business model', where the life cycle of the customer and the offering life cycle are mapped in parallel, through a continuous support relationship. Here, the PSS is sustained by both stakeholders through gradual alignment of business processes based on both parties' capabilities and organisational structure. The Offering Life Cycle Matzen (2009) can be used to describe the continuous match of customer needs and offerings from the supplying company in this parallel life cycle view of the supplier and the customer. A PSS will only be sustained through continuous problem identification and solution refinement or new service development matching changing product generations, which is why business relationship alignment strategies become important. Alignment and misalignment is an ongoing process and occurs between perceived problems and perceived solutions, wherein *time* can lead to greater alignment in the relationship (Corsaro and Snehota 2011). Another interesting element from the work by (Pine and Gilmore 1998, 84) is their description of 'learning relationships', where they point to the fact that the performance-based PSS can increase the quality of the system over time as it gets more knowledgeable of the customer and can customise their offerings based on the exact information based on a single user behavioural pattern or system efficiency condition. This is possible due to new technologies available, within SCM literature. Arlbjørn et al. (2011, 6) defined 'supply chain technology' as one out of three core element of supply chain innovation. The time domain is crucial for PSS in many different aspects. ROI's (return of investments) also refers directly to a certain period and duration of the system, estimating a point in time where the profit in relation to capital invested equals out. Service agreements where a performance is sold with e.g. Rolls-Royce and their Power-by-the-hour offering, they charge for *time* on wing. (charge per use) Service on demand: like repair, service technician on-call, spare parts, is if not a part of a service agreement, a *one point in time relation* between customer and supplier, an ad-hoc relation. (pay as you need).

6.1.8 Front and back-office

The customer contact, through which services are delivered or co-created, is of vital importance in connection to the perceived value of the customer. Therefore, any impact on this must be conceptualised and integrated in early PSS development. Service processes within the 'service organisation' can be viewed as going across internal and external borders of the company. The so-called 'service delivery system' can be analysed using two different angles: i) the front-office services, where the customer takes part in the activities and therefore is directly affected by the service; and ii) the back-office services, which are all the processes that are carried out remotely or 'behind the scenes' and therefore cannot be directly experienced and perceived by the customer (Shostack 1982). Silvestro et al. (1992) distinguishes front and back-office services due to the proportion of each in the actual service, which is supporting the fact that a service always will be influenced by both processes. This is why they must be conceptualised holistically. Structuring front-office and back-office activities is suggested by Zomerdijk and de Vries (2007) to be based on three design decisions not directly front and back but deciding on where customer contact should occur, which activities should be decoupled, and lastly which employees should be grouped and involved. Furthermore, they use an interesting definition of customer contact: "... *a direct encounter between a customer and a service provider that takes place in the same time but not necessarily in the same place, and has the opportunity for interaction."*

It has been identified that successful 'solution providers' have been organised into forming 'front-end-facing units' and 'back-end capability providers' together with a 'strong strategic centre' (Foote et al. 2001) An industry moving into a networked-based value chain 'ecosystem' where the sequential chain is 'dissolved' will make front and back-office services somehow different, as customer, user, end-user will change within the actual system, as co-design and co-operation is a reality, and hereby diffuse the borderline of company and user. Therefore, the line of visibility, which is by Shostack (1982) described as the line separating front and back-office, can change along the different activities in the PSS and become more important to manage.

In a co-operative network, the division of cooperative and competing activities is directly related to front and back-office activities. Front-office activities (activities where customer contact is present) are competing activities as these directly influences the perceived value of the customer, and thereby important customer contact and relationship creation can take place, where the back-office activities 'capabilities' is value-transferred through the front-office. Furthermore, the back-office can be viewed as resources, 'bundles of potential service' (Chandler and Vargo 2011, 39), which can be realised in value through activities and processes (e.g. the front-office activities) (Ng et al. 2012). Here, the strategic centre described by Foote et al. (2001) must uncover these potential services and potential values and bring them to play. A collaborative approach for 'potential services' can here be compared to back-office activities crossing company boundaries. Reflections and perhaps distinguishing between front and back-office activities can ease the identification of collaboration opportunities and therefore open the solution space wherein new partnerships and relationships can be found.

When reorganising a company (through a change management process) involving both internal and external relations, through ecosystem configuration, both back-office and front-office relations become important in the move towards a more competitive ecosystem. In solution oriented PSS where e.g. the value proposition is created based on taking over larger parts of the responsibility of the operation, or delivering a guaranteed performance, often leads to a more integrated system, as the supplier now is directly affected by the system functioning at the lowest life cycle cost as possible. Integrated systems require collaboration between the different suppliers as to create high quality and functional level but indeed also to allow an efficient and competitive service operation. Acquisitioning or partnering to reach the right system level (wherein the right competencies, and “system performance” can be designed and operated) still requires a network approach whether of an inter- or intra-organisational nature.

An example of front facing units that were changed and adapted based on a stronger service oriented business approach was a dealer’s network established to create MAN DIRECT. Sales personnel became sales consultants, and a broader contact was made to the customer organisation. The user, the driver, received training (Cakkol 2013).

6.2 Documentation of the intended support

This PSS tool Product/Service ecosystem characteristics (PEC) can be used within any of the PSS development strategies chosen. Though when getting closer to a service-oriented business approach, the network awareness and reconfiguration of this becomes more important. It could be argued that this happens when the focus is put on the design of the Product life cycle instead on the product itself. The tool should be seen foremost as a mindset changer. Refer to use scenarios for the PEC tool Table 24.

Table 24: Use scenarios for the PEC tool. (the letters and numbers is related to Figure 38)

#	Title and description of use scenarios for the PSS tool PEC
A1	**PEC for reconfiguration of the PSS ecosystem** *Using the PEC to conceptualise a PSS ecosystem reconfiguration, where new or changed relations are suggested to improve a PSS.*
	- Chose a Stakeholder mapping method and choose carefully the resolution of the ecosystem. - Describe a PS-offering using a scenario, e.g.: ‘Take-back systems’. - Sequence the flow within the ecosystem of this scenario. - Select a set of relations most critical to your business – and use the PEC to describe these. - On which characteristic could you focus to optimise the relation? i) bring in a new stakeholder; ii) move the activity to another point in time; iii) change the goal of the relation.

A2	**PEC of a PSS solution** *Using the PEC to describe a PSS solution* - Sequencing the activities needed e.g. using Blue-printing or User Activity Cycle - Choose the most critical activities and describe the network connected to these using a stakeholder mapping method and the PEC. - 1: Can any of the relations change characteristic 'between stakeholder' focus on the relation in Same function and Cross function (can suppliers collaborate across function or in the same function)? - 2: Can any of the stakeholders be present in any of the other activities within the sequence mapped?
A3	**PEC to barriers and challenges** *Using the PEC to bridge barriers or challenges in the transition towards an integrated product/Service-oriented business.* - Define a set of important challenges or barriers you think your company are facing. (or use below examples) Describe each of the issues using the PEC. - Service Engineering needs insight into the operational phase, 'how can this be secured?' - Contracting a certain performance to a customer '4$ per hour used' relies strongly on the collaboration with suppliers of the spare-parts, how can this be accommodated? - Imagine that you lease your sub-supplier systems or spares – how can this be established? - The customer requires a one-stop-shop solution and request that you integrate your system with a complimentary suppliers product – what changes do you need to make in your business?
A4	**PEC to collaboration** *Use the PEC to detail a PSS ecosystem collaboration to use in PSS development.* - Do this by using a stakeholder mapping in Macro level (simplistic – do not define the link between stakeholders). - Point out shared relations, and take point of departure in these. - Go through each of the characteristic and detail the relation as: - How it has been, how it is, how it could be…

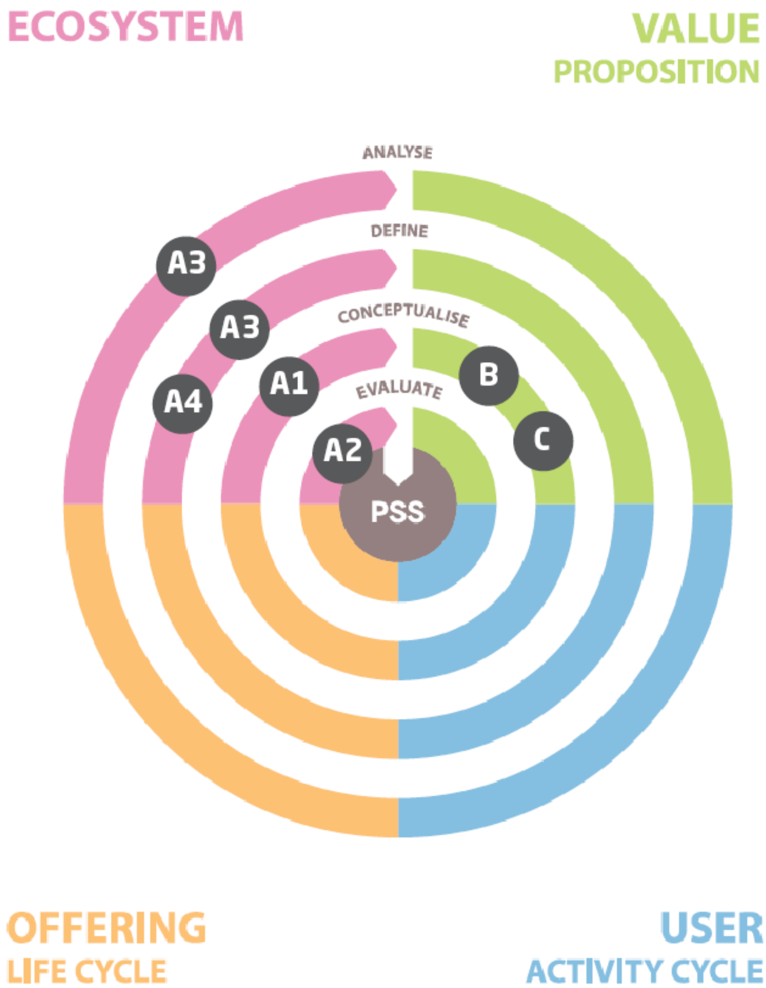


Figure 38: PSS conceptualisation framework –with PSS tools marked.

Figure 38 illustrates the developed PSS tools from this research project placed in reference to the PSS conceptualisation framework. The PSS tool PEC is marked as A1-A4, corresponding to the different scenarios developed and described in Table 24. Also the tools; PSS configurator (B) and the PSS cards (C) can be seen.

6.3 Summary

This chapter investigates research question 3: *How can a PSS conceptualisation activity allow an inherent network approach for co-development of the PSS-design?* This chapter has presented the prescriptive study 1. Presenting the development approach for the PSS ecosystem characteristics (PEC). The ecosystem characteristic developed during the literature study covers a total set of six characteristics:

- Between stakeholder (who)
- Relationship intensity (how)
- Goal of the relationship (why)
- Value creation (what)
- Time domain (when)
- Front and back-office (where)

Each of the characteristics are detailed and described in terms of how it is important for the development of a PSS. The descriptions of the characteristics are made through the lens of the PSS. This approach also distinguishes from previous work, carried out on network characteristics, as these characteristics are based on a phenomenon – the PSS – and the inherent ecosystem perspectives herein, one could argue, that the characteristics in this sense have been described based on a certain value logic in the ecosystem.

A set of use scenarios for the integration of the PEC tool into PSS conceptualisation is listed. The PSS ecosystem characteristics can be used as point of departure to ensure the thinking process of the PSS developer to include all perspectives when conceptualising new PSS solutions. Also the PEC can be a theoretical reference model a 'mental mindset' for further research and development of PSS tools for the PSS conceptualisation framework to integrate all the perspectives of the ecosystem.

The next chapter presents the evaluation of the comparative case study wherein the PEC tool was tested.

7.

Research evaluation

7. Research evaluation

This chapter is an evaluation of the framework and support developed and described in Chapter 6. This chapter elaborates on the descriptive study 2. It details the experiment within which the support (PSS tool PEC and the PSS conceptualisation framework) is tested. This is done through a comprehensive comparative case study involving two case companies. The chapter starts by introducing the actual experiment and the data captured, hereafter an in-depth analytical generalisation process is described, using a set of five measures, which spells the process for the evaluation.

The aim was to evaluate the developed support – the PSS Tool PEC and the PSS Conceptualisation framework through an in-depth analysis of the effect the support had which was based on a set five measures. For this a comparative case study was set-up and conducted (refer to the research approach in chapter 3 for a detailed description and overview), with a set of core activities; three distinct development workshops, initial network analysis, design of the co-development activity and in-depth interviews in each of the companies prior to the comparative case study. The findings from this chapter are a means to achieve the desired situation, described by the criteria in chapter 1. The previous chapter has presented the systematically developed support tool PEC which is to be evaluated in this chapter. In Design Research the *support* can take many forms (Blessing and Chakrabarti 2009) as: *Guidelines, methods, re-organisational proposal,* and mediums as: *paper, software, models* and *workshops*. This for this research project is a mix of all the mentioned. The support described is the *Intended Support,* by which the desired situation is to be reached. The *Actual Support* (which is the one applied in the comparative case study) will function as a demonstrator, creating a platform from which sufficient evaluation of the core contributions can take place (Blessing and Chakrabarti 2009). As the desired effect is to be found in an industrial setting, in the maritime industry at two participating companies, a careful balance has been conducted between making sufficient evaluation and matching the possibilities and the willingness at the companies. Which have influenced the final choice of *The Measurable Success Criteria*. Therefore an evaluation plan 'the analysis' of the effect of the support tool is described together with the actual analysis of the findings. Some activities and charting are conducted by the researcher – all of which is validated by an iterative process with the participating companies.

7.1.1 The actual support

The Support tested within the comparative study is a combination of the 'PSS Ecosystem Characteristics' (PEC) and existing frameworks and tools. The six PSS ecosystem characteristics are used to analyse and identify the case companies by: analysing historic and current relations; finding and describing a new collaboration opportunity for the stakeholders; and design conceptualisation activity.

Table 25: Overview of the different elements of the comparative case study

Element in the study	Description
Initial Network analysis	The analysis conducted in the explorative research phase was base for the network analysis. (See chapter 5: industrial research foundation)
PSS Tool: PEC	Selection, description and analysis of the two case companies, analysis of potential future collaboration scenarios. (Using the PEC tool) See section 7.1.2 PSS ecosystem analysis of the two case companies and Table 27 for collaboration scenarios
PSS Conceptualisation framework	Design of the PSS conceptualisation co-development activity. Using the PSS conceptualisation framework and the PEC tool (the development workshop) See details in Table 26.
Semi-structured interviews and creation of representation models.	Initial interviews + development of models and representations at each company prior to the development workshops.
Development workshop 1 (WA)	PrimeServ Frederikshavn
Development workshop 2 (WB)	Alfa Laval Aalborg
Development workshop 3 (WC)	MAN PrimeServ Frederikshavn + Alfa Laval Aalborg

Table 26: The comparative study detailed by describing the development workshop

#	Elements	Description
1	**PSS development framework**	A unique route within the framework; A focus is put on (1) the value proposition as point of departure, which was described as: '*We offer a total Life cycle management of your ship performance –securing maximum operation hours and minimizing your total life cycle cost'* in a PSS development phase 'define'. Hereafter the (2) offering life cycle and (3) user activity cycle simultaneously, in an analysis activity. Then a pure focus at the (4) Ecosystem dimension also analysis. Lastly the (5) conceptualisation activity accelerated in where all four dimensions were integrated.
2	**Activities within the PSS development workshop.**	The workshop was named: *collaborative networks, synergy through affinity.* The aim for the workshop was stated as*:* - Strengthen the companies' competitive advantages on a global scale, enabling the companies to develop or

		improve Product/Service-systems. - Strengthen knowledge and experience sharing between the companies. - Explore and exploit inherent and unused possibilities of collaboration between the companies to increase the competitiveness of a/the PSS solution. - Give a general understanding of PSS for both companies – broadly in the organisation. **1) An introduction to PSS**: Defining this through examples, and theoretical frameworks. Presenting the PSS conceptualisation framework. **2) Investigation of the offerings portfolio** already compiled from each company. Listed by the service design strategy framework. Presentation and discussion of each company product/service offerings. **3) Identification of shared presence** at the customer activity cycle. And a discussion of prioritised importance of these. A discussion of possibilities for a strengthened presence at the different activities, and offerings towards the customer, as separate companies or together. [D: Customer Activity Cycle, E: Activity flow diagram is on the table] **4) Investigation of the stakeholder map**, identification of the crucial stakeholder and relationships in the network. Reflection on which similarities exists between the companies. Marking of a set of prioritized relations influencing directly the companies' value of the offerings. [A: The stakeholder map is on the table] **5) Pure conceptualisation activity. Developing new PSS-offerings**. By identifying new areas in the customer activity cycle where a possibility exists, to add a shared value to the customer. [A: Stakeholder map, C: offer portfolio, D: Customer Activity Cycle, and Activity flow diagram is on the table] [Numbers and letters refer to Figure 39]
3	**Collaborators**	W1 and W2 – Intra-organisational collaboration. W3 – inter-organisational collaboration. (Refer Table 14 to see who were involved) In each of the workshops, the constellation was three groups, and half way through the workshops, the groups were shuffled.
4	**A set of PSS Tools**	Five different tools were used PSS ecosystem Characteristics (implicitly), Stakeholder network, User Activity Cycle, Activity flow diagramming and Offer portfolio.

5	**Unique representations**	A set of unique representations for each of the tools: Customer Activity Cycles charted with a mapping of the company's presence in each activity. Offer portfolio a compilation of brochures in a binder. Activity flow diagramming also with the stakeholders charted in each activity. The stakeholder network mapping. Two versions: i) for W1 and W2 a stakeholder network with main stakeholder groups and *their own company* detailed by intra-organisational links. i) for W3 the stakeholder network had main stakeholder groups and *both* companies represented through detailed intra-organisational links.
6	**Facilitation**	The author facilitated the workshop. Presenting the different activities and handed out the representation models. Each group also had a facilitator present during the all the activities – with the role as supporter to participants and taking notes and transcribing the workshops real-time.

Table 26 above, details the comparative study, by detailing the development workshops. The experiment has one uncontrolled parameter, parameter 3 'collaborators' namely the stakeholders participating. W1 and W2 conduct intra-organisational collaboration, and in W3 the two companies are brought together, and conduct inter-organisational collaboration (co-development) during the conceptualisation activity. Also a small change were made to one of the models, namely the stakeholder network, therefore parameter 5 had a change – the representation were slightly changed to include both companies in the same representation.

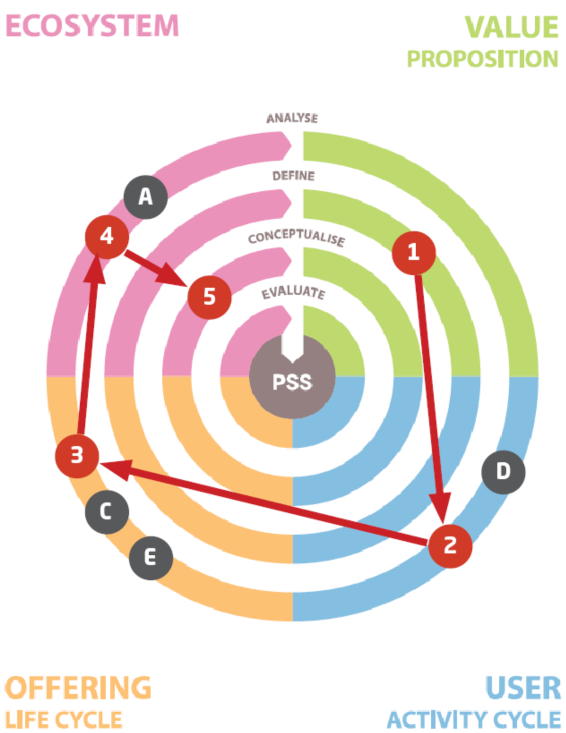


Figure 39: The actual support – marked in the PSS conceptualisation framework followed in each workshop

The following section has two main elements; first an analysis of the two companies and thereafter an analysis of the workshops.

7.1.2 PSS ecosystem analysis of the two case companies

Using the PEC tool, the case companies' different relationships and affinities within the PSS ecosystem are detailed. This serves as a qualitative validation of the tool, together with an illustration of how the characteristics can be used.

Case companies before the comparative case study:

This section uses a retrospective analysis of the relationship between the case companies up until the comparative case study. In the stakeholder network Figure 17 in the industrial research context chapter: i) many of the relations are shared and understood as they have a similar position within the network; and ii) the relations between the two case companies are manifold. This will be presented below.

Between stakeholders:

Looking at the relationship between PrimeServ Frederikshavn and Alfa Laval Aalborg, they formed an inter-organisational relationship which consisted of many different relationships and constellation of these. They had a classic Trans-function relationship due to their Supplier/customer-relationship. Alfa Laval is a supplier of manufactured goods to PrimeServ Frederikshavn, delivering spare-parts and sub-systems. They also formed a co-operative network through 'context' trans-function integration, where they collaborated on technology development R&D. Furthermore, they also both took part in different knowledge networks like a public/private relationship: *Green Ship of the Future* and *Hercules* and of course the innovation consortium PROTEUS. As both companies are service providers to the shipowner, they also form a same-function relationship and in this relation they also act as competitors. They therefore act as individual stakeholders in sub-networks (R&D network) and in larger networks (collaborating parties e.g. research consortium). The different relationships are also mirrored in the departments in collaboration. For the regular buyer/seller relationship the relationship is characterised by which department are activated; which in this particular relationship is the *sales* department at PrimeServ Frederikshavn and the *procurement* department at Alfa Laval Aalborg. In another more collaborative relationship in the Retrofit project where they conducted project-based development together, the department *Retrofit* at PrimeServ Frederikshavn and the department *Service* at Alfa Laval Aalborg were collaborating.

Relationship intensity:

The intensity of the relationship can be described as a combined Ad hoc and regular in a strategic supplier relationship. They form a regular transactional buyer seller relationship, where Alfa Laval Aalborg sells spares and sub-systems to PrimeServ Frederikshavn. They also form a relational link in a risk-sharing partnership where they have close collaboration and share development, implementation, and evaluation in Retrofit R&D development, a project-based development. The relationship intensity is mostly characterised by i) coordination, where they had their own goals, aligning activities as lobbying and knowledge sharing in PROTEUS; and ii) close collaboration where they shared responsibility and goals and actual development activities together.

Goal of the relationship:

In their customer/supplier relationship, maintaining a cost effective and reliable system were in focus, along with selling high quality products and systems, and met any need for spares and repairs timely. Within this relationship, they had contradictory goals (e.g. they could both sell spares and to a limited extent service one another's systems). On the other hand, the goal of the relationship around R&D activities was shared and focused on the actual Design Object – technology development and engineering design as well as service development as the retrofit is part of after-sales, where existing ships are converted to hold new functions. This project can also be described as having a close link to business strategy as the new technology gave the suppliers a 'market opportunity' to offer a new technology that could meet future regulations. This can be said to be a goal-oriented network as they aimed to be market movers of a new technology. While efforts were coordinated as they simultaneously collaborated on lobbying activities to influence a timely launch of the new regulation. The level of change in both relations can be described as being in the current network (Möller and Rajala 2007) but with focus on radical product innovation.

Value creation:

The value can be seen at different levels. Looking at the classic relationship, the deliverables between the two stakeholders are physical goods in exchange for money on an ad-hoc basis in a classic service agreement. The deliverables were supplies from Alfa Laval Aalborg to PrimeServ Frederikshavn, who would assembly these into large Total Propulsion Packages; also they would purchase extra spares for part packages to sell in New Engine sales. Within their relation of R&D development activities, the deliveries between the two companies were also knowledge, branding, and resources. The R&D activities were concentrated around a new approach for exhaust gas cleaning fitting old vessels in a project-based development project. In this context, the two companies would in collaboration offer shipowners a customised retrofit solution, and in this manner the two companies made system integration (Matthyssens and Vandenbempt 2008), aggregating different value propositions as described by Tan (2010). Also a value creation, their lobbying activities pushed towards a new regulation for a new emission level and being able to support the shipowners in a long-term investment to meet the future regulations of the TIERII. In the research consortium PROTEUS, the two companies also shared information and knowledge and together with the rest of the consortium initiated a larger movement within the industry, namely that of the changed focus and move towards an integrated-product/service-oriented business approach. This potential effect within the industry was aimed at a changed network and radical shift in business strategies.

Time domain:

The relationship between the two companies was mostly taking place in the pre phase of the User Activity Cycle, in supplies of product and spares. In the Retrofit project, they were collaborating and offering the integrated product/service solution in the use phase of the ship. They did not collaborate on offering a broader service portfolio together. Both companies were present at multiple at the e.g. Shipowners what Vandermerwe (2000) refer to as critical activities, with a potential for Same-Function collaboration, moving closer towards the customer in many different service offerings, here to mention e.g. the Academia – where training were offered to the crew and to the Shipowner organisation. Furthermore looking at time and duration, the length of a relation varied. The customer/supplier relationship was continuous, but within one-point in time; purchase. The PROTEUS consortium were a defined project period, a temporary network in the ecosystem, The Retrofit project were also following a project time scale.

Front and back:

Looking at the front and back-office activities, they primarily collaborated on the back-office activities. Both companies had what Foote et al. (2001) refer to as front-facing units. PrimeServ Frederikshavn had a dedicated Business After-Sales unit, and Alfa Laval Aalborg had a department focusing on after-sales services. The Retrofit project was an example where they were collaborating close to the customer in direct contact with the shipowner, sharing the sales and communication channels and meeting customer demand in direct collaboration in a project-based development project.

7.1.3 Collaboration opportunity

Based on this analysis of two companies within the ecosystem, using the PSS Ecosystem Characteristic as guiding elements, two scenarios were developed (listed in Table 27) short term and a long term scenario, whereas the short-term which was tested in the comparative case study was aimed at catalysing the relationship towards a more strategic relationship long-term.

Table 27: Desired state - aim for the co-development activity – within the comparative case study

	New constellation (to test in comparative study):	To bring them towards…
Between stakeholders	- Bringing new departments together – managers, technicians, and developers. - Co-operation	- New stakeholder – Venture in turnkey propulsion solutions
Intensity	- Collaboration relational - Business strategies. - Co-development of new solutions	- Potential long term relational collaboration
Goal	- Opportunity network - Market mover	- Strategic
Value creation	- Shared performance system - Improved academia offering	- Radical / new market - Performance-based solutions
Time Domain	- Pre-phase: proactively development of new solutions – before requested by customer.	- Covering all the Product-life phases. - Supporting the customer before, during and after usage.
Front and back-office	- Back-office development Front-facing development – in close collaboration with the customer.	- Front-facing department for After-market

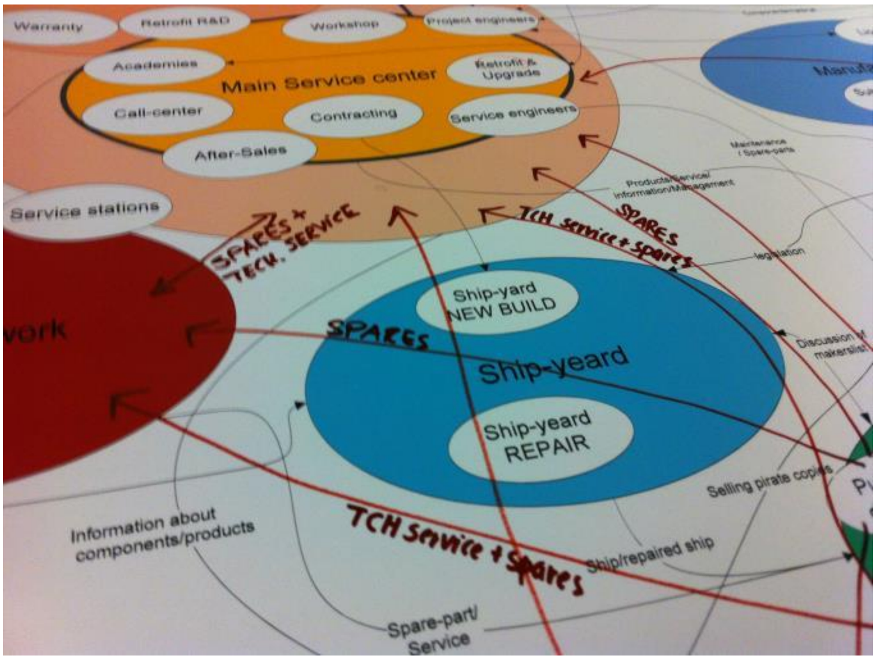


Figure 40: Picture from the co-development workshop: The stakeholder network was used to identify critical stakeholder, and to map the unique links between the stakeholders.

Figure 41: Picture from the workshop at PrimeServ Frederikshavn. The stakeholder network is on the table

Figure 43: Picture from the workshop at Alfa Laval: The offer portfolio is used in a synthesis activity

Figure 42: Picture from the co-development workshop: Using the User Activity Cycle to identify shared presence at the customer's activities

7.1.4 Analytic generalisation as evaluation approach

Validating the findings from an action-research approach has some difficulties, which is why the process of *analytical generalisation* described by Yin (2009) is chosen to guide the *evaluation* of the study – to state the plausibility of the findings (not the validity). This process can be described as an interpretive analysis, screening for patterns and possible explanation throughout the evaluation. The case study is exactly chosen to cover contextual conditions, to be able to retain holistic and meaningful characteristics. This process is led by the inquiry if or if not the findings provide theoretical insight that has a sufficient degree of generality to be projected to other contexts. There is a risk for bias when conducting flexible research designs, as is the case with action-research which is outside the laboratory. Robson (2011) claims that rigour in this kind of research needs to cover possibility for bias by:

- *Reactive* (e.g. Hawthorne effect); take into account that bringing the two companies together might have an effect on its own.
- *Respondent* (e.g. social desirability bias); the participants at the workshops might have influenced the outcome, due to their desire for a particular topic or outcome of the workshop.
- *Researcher* (e.g. preconceived ideas); throughout the pattern identification and explanation building, bias might be towards the desired outcome.

Besides possibility for bias, threats lie also in the researchers, description, interpretation, and choice of theory, which can be approached by analytical and theoretical generalisation, where theoretical insights (generalisable claims) are developed by; building or testing theory and/or comparative analysis across multiple cases.

7.1.5 The evaluation based on five measures

The evaluation, which as mentioned is based on a process of analytical generalisation, uses a set of five measures, which is derived from a combination of insight from the DS1 the explorative phase, and the literature from both PS1 and PS2. The measures are also selected based on the possibility for operationalising these in the comparative study. The measurable success criteria are as listed in chapter 3 section 3.1.2

Measure	An operational description of the measure
PSS efficacy / efficiency ***...more network-oriented PSS Concept Elements.***	How did the method influence the PSS ecosystem Dimension? Did the method create PSS Concept Elements integrating network considerations, new roles, relations, structures?
PSS offerings ***...more offerings and increased novelty.***	Does the support increase/decrease the number of PSS CE? Are the offerings new or improvements to an existing offering? If the efficacy increases is it affecting the amount of PSS CE or the novelty?
PSS Service continuum strategy ***...more service orientated.***	Investigation of whether the PSS CE developed is more or less service oriented. E.g. if the method results in more PSS CE with ecosystem perspectives included does it influence servitisation simultaneously?
PSS framework ***...the coverage of the PSS framework.***	The goodness of the PSS CE, a concept should be described by the four PSS dimensions. How well does the PSS CE cover the four dimensions? Is some perspectives more used than others in the conceptualisation with the proposed method?
PSS feasibility ***...more feasible.***	If all of the above, increases; better PSS CE with holistic perspectives on the ecosystem Dimension, and increased service level, are the PSS CE feasible at all?

Table 28: The five measures for the analytical generalisation process

As the process of analytical generalisation has a core aim of pattern finding, the significance in the measures of the analysis does not serve a goal of its own, as would be the case of statistical generalisation. Yin (2009) claims that the sample size should not be critically reviewed; it merely represents an experiment from which analysis can be carried out. To give thorough details from which the evaluation is based, though a few details are presented in the following.

To be able to conduct the evaluation yet another view of the conceptualisation process and its elements was taken, named the PSS Concept Element (PSS CE), which was developed in the Prescriptive Study 1.1:

- *During the process of conceptualisation a pool of PSS concept elements will be created and of these a configuration of a PSS concept can be made. The Concept Elements can be purely connected to one PSS dimension or multiple, they are fragments from which multiple of these brought together compose a complete PSS concept.*

The analysis is carried out by use of audio and video recording the development workshops, from where the material was transcribed, and coded. The code was developed to be able to evaluate on the five measures. A set of rules (refer to Appendix E p. 273 for an overview) were developed by an iterative process of comparing a manual and automatic categorisation of true and false, which consisted of 91 different constellations. The process had two steps: 1) The rules were developed and applied, from where an automatic true/false list was created; 2) This list was then closely examined by comparison to the manual list to identify inconsistency and adjusting the rules accordingly. Iterations were made and the final code of 12 different rules was chosen to be used throughout coding the PSS Concept Elements. The rules were also developed to collectively act as a checklist of whether the actual coding was correct or not. Refer to p. 260 for an overview of the actual code.

A total of 128 PSS Concept Elements were found. Based on the six categories (A-G) and the 23 different variants, a set of 91 different types of PSS Concept Elements could be mathematically derived. Applying the rules described in the above, 48 of these are possible. From the total amount of possible PSS Concept Element constellations, 36 PSS Concept Elements are 'Front-office' constellations and 12 PSS Concept Elements are 'Back-Office'.

7.2 The analytical generalisation of the comparative case study

The following sections will go through each of the five measures and a set of cross-analyses. In each section analytical and contextual elements will be highlighted, to illustrate patterns and bring a continuous judging of the effect the support had. For each of the measures a set of graphics are provided to support the representation of the findings. During the different sections examples from the workshops will be highlighted, presenting specific PSS-CE their description and the transcription connected, to support the evaluation. Throughout the analysis – when needed refer to Appendix D for the code and Appendix E for the rules.

7.2.1 # Offerings

In total across all three workshops 128 PSS-CE was developed, 97 PSS-CE constituted 'offerings' – they were characterised as front-office an could be mapped on the service continuum. These distinguish from the rest 31 PSS CE as they are direct offerings to the customer, or changes that the customer will perceive. The distribution of the offerings is illustrated in Figure 44. Of the 97 offerings, 45% of these were created in WC, which is only 6 % more than WB. Therefore, the quantity cannot be said to rise neither it is reduced. Comparing WA and WB, there is a large difference in the PSS-CE conceptualised, WA with 16% and WB with 39%. This is a great difference, which is important to reflect upon during the rest of the analysis as this will be an integrated part of any later analysis. Two parameters (dependent variables) might have influenced the spread: i) the number of participants was slightly higher in WC; and also ii) the background of the people participating was different. In WA with PrimeServ Frederikshavn, the participant had more experience with service development than product development, though none of which were formalised. Alfa Laval Aalborg had both after-sales and new-sales at the site location and also R&D of new Product development.

Looking at the offerings spread division in new offerings vs. improved existing offerings (refer to Figure 45) there is no significant change between the three workshops. This indicates that the offerings were conceptualised mostly with no reference to an existing offering and therefore represented a new offering to the companies.

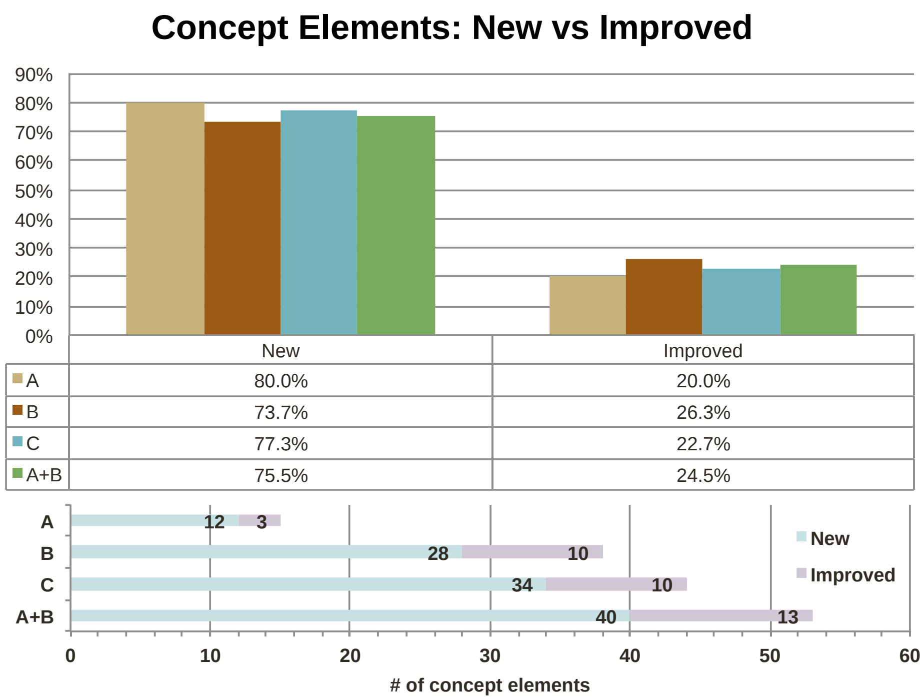
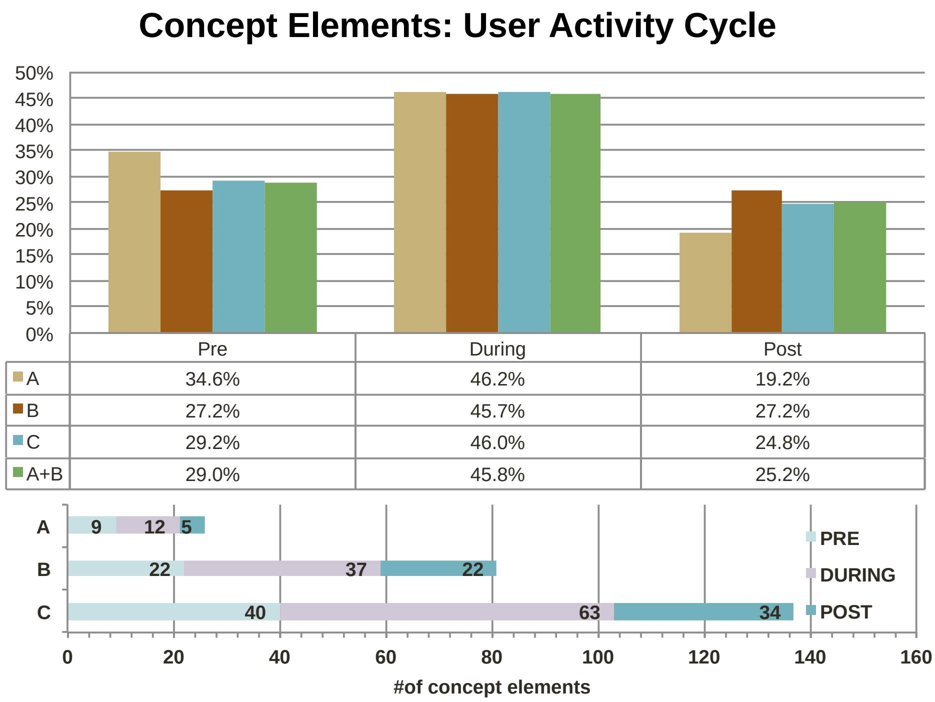


Figure 45 # Offerings: the split of the PSS CE on new offerings vs. improved offerings (n=128)

The offerings spread in the User Activity Cycle, in connection to pre, during and post use, also illustrates that there were no change between the workshops.



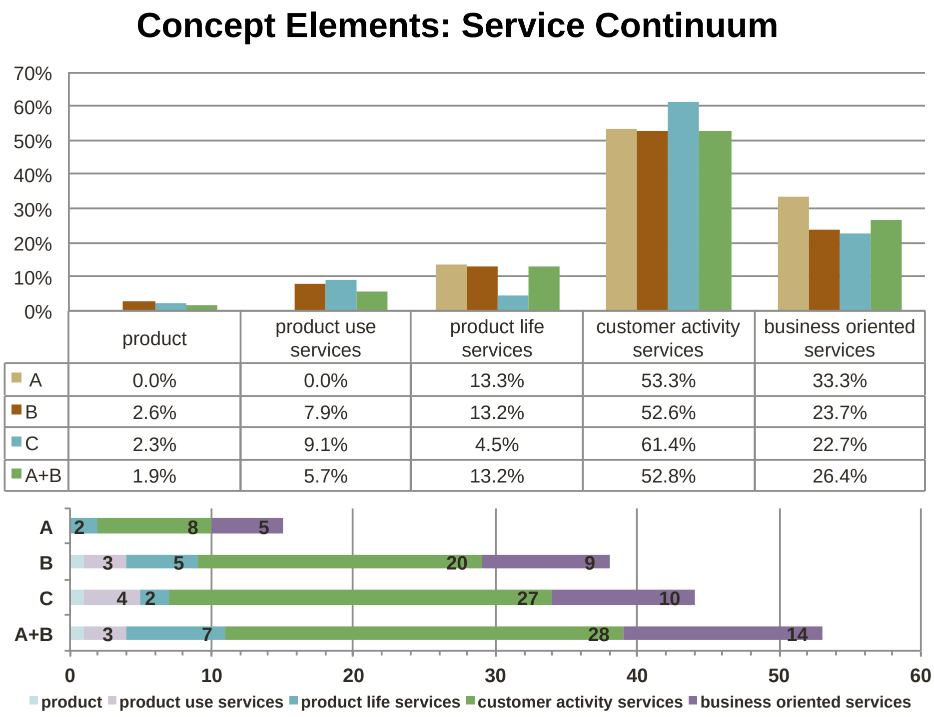
	Pre	During	Post
A	34.6%	46.2%	19.2%
B	27.2%	45.7%	27.2%
C	29.2%	46.0%	24.8%
A+B	29.0%	45.8%	25.2%

Figure 46 #Offerings: PSS CE and their coverage on User Activity Cycle with pre, during and post usage. (n=128)

The majority of the offerings were connected to during usage, which was not a surprise as the services to support the product or the user of the product directly as e.g. preventive or proactive services are the first services seen in a transition towards a more service-oriented business strategy. WA, as compared to WB and WC, had a larger amount of offerings in pre usage. This could be due to the fact that PrimeServ Frederikshavn was looking into possibilities for increasing their sales of service agreements and improving their knowledge of customers to better match their service needs.

7.2.2 # Servitisation

The PSS-CE spread on the Service continuum had a general peak across all workshops at Customer-activity services with more than 50% off all offerings within this category, and with an approximately 10% increase at WC compared to W (A+B). The support developed was aimed at an increase in the service-oriented offerings, such as product life services, customer activity services, and Business Oriented Services. Most of the offerings are covering multiple service strategies in the service continuum, and therefore it brings a critical element to the categorisations of the different PSS-CE conceptualised in the workshops. Many of the PSS-CE cover multiple of the strategies, in which case the most representative category was chosen.



	product	product use services	product life services	customer activity services	business oriented services
A	0.0%	0.0%	13.3%	53.3%	33.3%
B	2.6%	7.9%	13.2%	52.6%	23.7%
C	2.3%	9.1%	4.5%	61.4%	22.7%
A+B	1.9%	5.7%	13.2%	52.8%	26.4%

Figure 47 #Offerings: PSS CE spread on the Service continuum (n=97)

The large amount of offerings directed towards the customer activities were not surprising as the suppliers (throughout the consortium) were focused on the customer by supporting the customer directly, or through call-centres, inspections, training, etc. This represented the current level of servitisation within the industry. Two examples of a PSS Concept Element focused on the *Customer Activity Services* are listed below:

- **PSS-CE #23 WB: Condition-monitoring + shared access to data:** Condition monitoring of the system. The customer can have access at different levels and thereby choose different price levels

"... condition-monitoring of everything. That would be a good thing to have, as a future offering. Where also the customer could access the data, this could be done through different access levels ..." [Workshop B]

- **PSS-CE #70 WC: Support customers in new updates of the ship:** Improve support to the customer through informing better on new updates on the ship. E.g. if a product is being replaced in a suppliers portfolio due to a defect, a better information system for the customer could be beneficial.

"... We have already written down documentation, but if a problem arises on board it must be possible to seek help, maybe the virtual ship. If a boiler is leaking, what can be done? Instead of him calling the main-office all the time, I think we have responsibilities within the company to be up to date;

we need to be good at informing the customers about new initiatives and guides for how to operate ..." [Workshop C]

The transition to become a more service-orientated company often starts with service add-ons, like extended warranties, spare part packages, etc. (Martinez et al. 2011b) not directed to any specific service levels but in nature being single elements to supplement existing offerings. These services are often a non-integrated part of the product, which is why they might appear more frequently in the workshops.

Business Supporting Services where the suppliers are supporting the customers' businesses by taking over larger amount of activities by outsourcing or partnering (e.g. maintenance as with PrimeServ and EMC) demands new capabilities in the companies. Supporting the customer activities are most of the time done through existing competencies within the companies. The channel through which this is offered varies together with the business strategy behind it as, for example, the established revenue mechanism. When being able to offer customer activity services, it is a possible indicator of that a business opportunity could lay within *Business Supporting Services,* as in theory all the different Customer Activity Services can be transformed into a business service, by outsourcing it to the supplier or by other partnership agreements transition towards the last service level.

Examples of a PSS Concept Element focused on the ***Business Supporting Services***:

- **PSS-CE #9: Performance solutions – responsibility for energy balance**: Taking over responsibility of energy balance of the 'System'. Keeping in compliance due to regulations on energy. This could be in collaboration with a legislation company

"... Recently I thought about a new service as well, due to all this policy, that you need to have an energy balance of your vessel, older vessels need to show that they are doing something in the right directions. I think when an engine is at a service centre we could offer a survey of the engine room, of how they can save energy if we could find a legislator company at the harbour that could look at this ..."[Workshop A]

Across all three workshops, the last two strategies at the continuum, the customer activity and business supporting services, were counting for more than 75% of all the PSS-CE conceptualised. The support tool can therefore be argued to have a direct correlation with the service-level of the offerings conceptualised. Though there is no change between the workshops—and therefore the unique constellation with the two suppliers had no influence on the spread on the service continuum.

The two companies were focused on the customer, and this allows for proactive support, which can increase the product quality by continuously throughout the Offering Life Cycle support the system/customer. It also shows that they had customer channels in place, which is vital for a service-oriented company to get the right amount of information backward in the company, and also reveals possibilities for moving further into *Business supporting services.*

Lastly, there was a slight drop at WC in the *Product Life Services* with WC at 4.5% and W(A+B) at 13.2%. Only one PSS-CE had a core focus on take-back systems found in WA.

"... The process that the customer faces now, where he needs to get rid of a few ships, and scrapes a few, then it could be an idea to take back some of the old 'products', if they are for example 15 years old, they could simultaneously buy new from us. There´s a lot of business opportunities ..." [Workshop A]

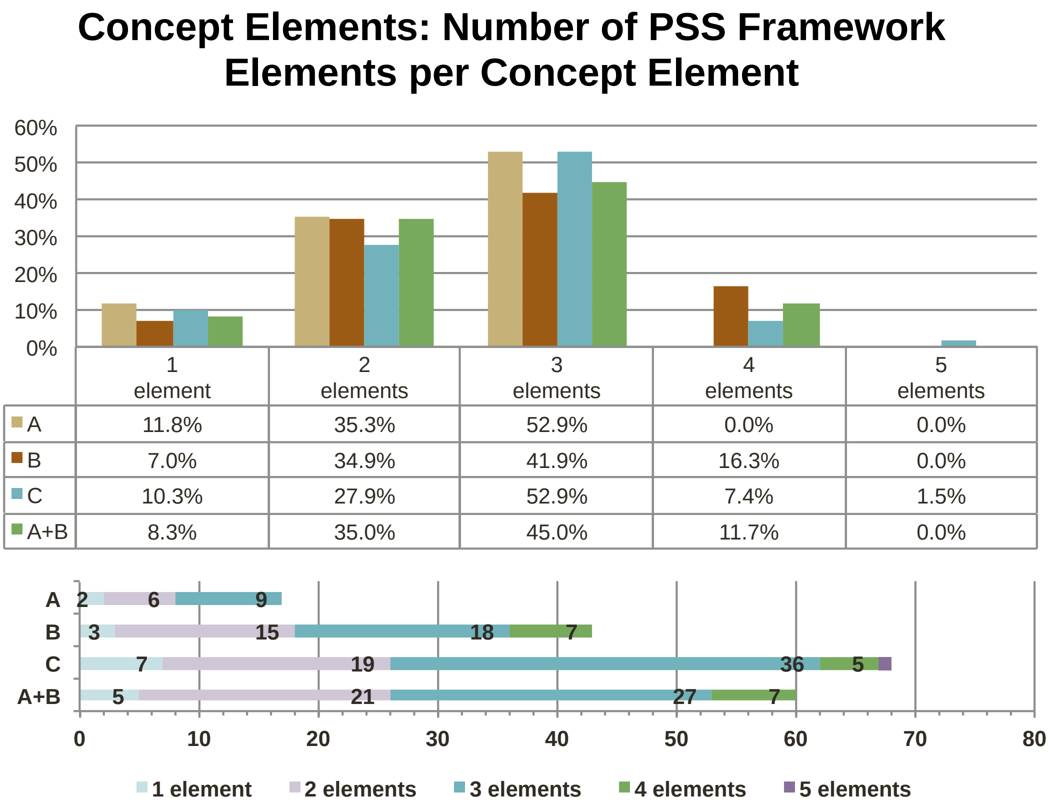
Leaving the product services as the least conceptualised offerings, with less than 3 % (0 % in WA and 2.3% in WC) and across all workshops less than 10 %), were within product use services. This can be a direct effect of that these are currently already existing in both companies. From all 97 different PSS-CE only two of these are focused on the product one in WB and one on WC, and none in WA. The lack of PSS-CE covering pure products in WA, comes as no surprise as PrimeServ Frederikshavn represents an after-sales division of the company, with a history as a R&D centre of four-stroke engines, but no longer holds active new product development at this site.

7.2.3 # Holistic

Most of the PSS-CE had a description of using two or three PSS framework elements. Only in WC a PSS-CE had perspectives covering all five PSS framework elements.

- **PSS-CE #61 WC: Integrated products - Turnkey solution:** Multiple suppliers collaborate to create a holistic system where the products are integrated. Integrated product development or adjusted assembly. The products are suggested to be sold through one supplier [Workshop C]

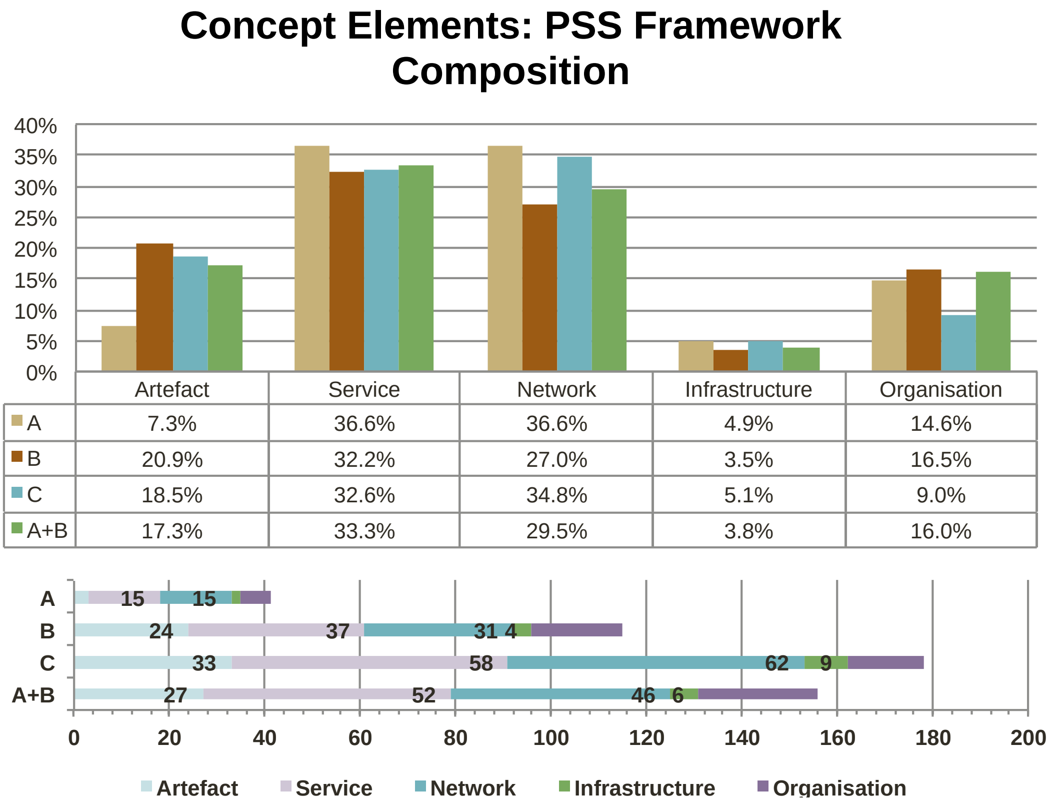
"... Some of our products influence each other here you could profile each other. This is the holistic view. Total solutions, instead of they (the customer) go and fix it themselves. Maybe it's a bit more expensive, but when the system doesn't work, you will have seven suppliers pointing at each other, and claiming everyone but themselves to be responsible… it could be that the solution should be bought through only one of the suppliers ..." [Workshop C – quote from Alfa Laval Aalborg]



	1 element	2 elements	3 elements	4 elements	5 elements
A	11.8%	35.3%	52.9%	0.0%	0.0%
B	7.0%	34.9%	41.9%	16.3%	0.0%
C	10.3%	27.9%	52.9%	7.4%	1.5%
A+B	8.3%	35.0%	45.0%	11.7%	0.0%

Figure 48 #Holistic: PSS CE and the number of PSS framework elements referred to in the description

This reflects the fact that the PSS-CE is fragments of and not finished concepts, detailing a complete PSS design by all five elements. The *Support Method* is aiding a compilation of a concept element pool, through which a further conceptualisation can be created, with a more systematic approach, combining the PSS-CE with holistic PSS designs.



	Artefact	Service	Network	Infrastructure	Organisation
A	7.3%	36.6%	36.6%	4.9%	14.6%
B	20.9%	32.2%	27.0%	3.5%	16.5%
C	18.5%	32.6%	34.8%	5.1%	9.0%
A+B	17.3%	33.3%	29.5%	3.8%	16.0%

Figure 49 #Holistic: PSS CE and the integrated PSS perspectives from the different PSS dimensions

Detailing which of the PSS framework dimensions were covered, a focus across all three workshops was at the Service and Network elements, with an average of 32%. The aim of the development activities at the workshops was exactly that of the network and service perspectives, which can indicate that the support is influencing the focus on service and network conceptualisation. Though bringing the companies together in WC and the strengthened focus on the stakeholder relations, should have increased the focus on the network perspectives in WC, which was not the case, looking at the framework coverage of this. Furthermore at WB a slight drop in Network elements compared to WC and WA were observed. This could be connected to the company undergoing a large internal reorganisation and therefore already focused to a large extent on internal and external networks. Looking at WA, the difference between Artefact and Service elements was the highest with approximately 30% compared to WC with 18.5% and WB 11.3%. WA had very little focus on the Artefact in the PSS-CE description, which again could be caused by the organisational focus on after-marked services or the lack of R&D new product development engineers. The PSS-CE had minimum usage of infrastructure and organisation perspectives, with WC with the lowest inclusion of the organisational element with a coverage of only 9% compared to W(A+B) 16.0%. This could indicate that the support tool and stakeholder constellation in the WC workshop had an effect on the focus on organisation in the PSS-CE. Bringing the companies together therefore indicate that focus is moved away from internal organisational perspectives. It is not to say whether the decreased focus on organisational internal structure could also be due to confidentiality issues.

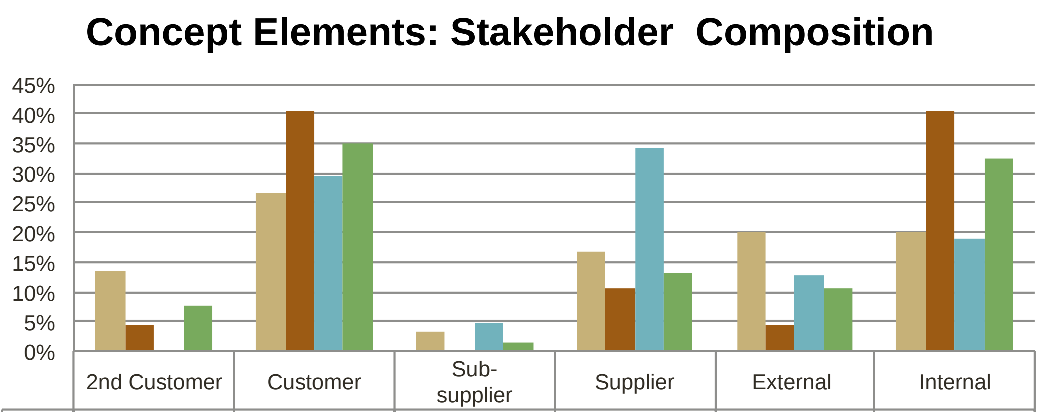
7.2.4 # Efficacy

The key measure Efficacy is measured by three different categories: i) stakeholder type, ii) collaboration type, and iii) front vs. back-office activities. This measure is the one with the greatest difference between WC and WA & WB across all three categories. If we look at the stakeholder types mentioned (Figure 50) the inclusion of supplier relations in the PSS-CE increased at WC, with a total of 34% compared to WA with 16.7% and WB with 10.6%. Specific 29 PSS-CE's included perspectives of suppliers, compared to 5 PSS-CE in WA and WB. Also, there is a slight increase in sub-supplier focus. The PSS-CE #22 at WC illustrates how the suppliers were an integrated part of the PSS-CE.

- **PSS-CE #22: Monitoring across systems and product groups / across suppliers:** Instead of each supplier having their own monitoring system, suppliers could collaborate on one platform on-board and gather data from this.

"... monitoring: then you have MAN, and then you have Aalborg Alfa Laval, then we have... around 20 other suppliers, does everyone needs to have their own monitoring equipment on board? - It's just data we collect, they should maybe be collected on one platform, instead of everyone has their own ..."[Workshop C]

The 2nd customer is more important for MAN PrimeServ Frederikshavn as they always sell directly to the shipowner, where Alfa Laval Aalborg does not sell directly to shipowners across all their product groups. This might be mirrored in the PSS-CE conceptualised as WA had 13.3% with the 2nd customer focus compared to only 4.3% at WB.



	2nd Customer	Customer	Sub-supplier	Supplier	External	Internal
A	13.3%	26.7%	3.3%	16.7%	20.0%	20.0%
B	4.3%	40.4%	0.0%	10.6%	4.3%	40.4%
C	0.0%	29.4%	4.7%	34.1%	12.9%	18.8%
A+B	7.8%	35.1%	1.3%	13.0%	10.4%	32.5%

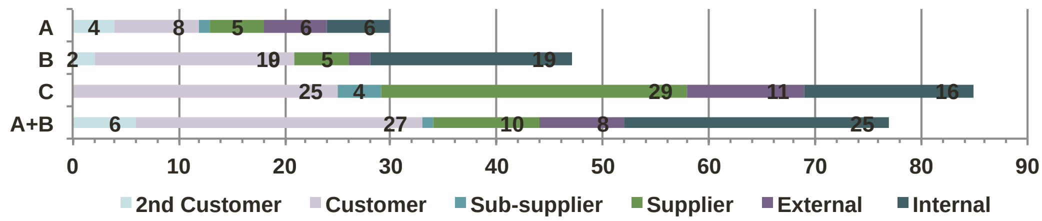
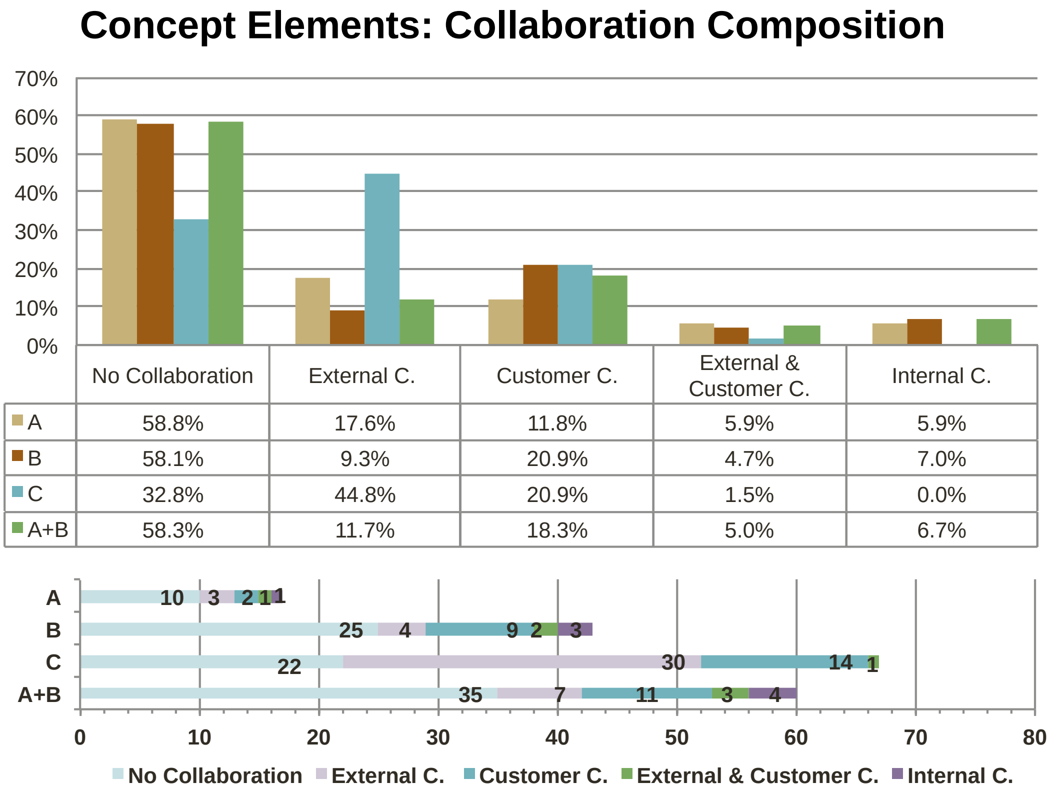


Figure 50 #Efficacy: PSS CE and the composition of stakeholders - in percentages how many stakeholders were included in the description of the PSS CE (n=128)

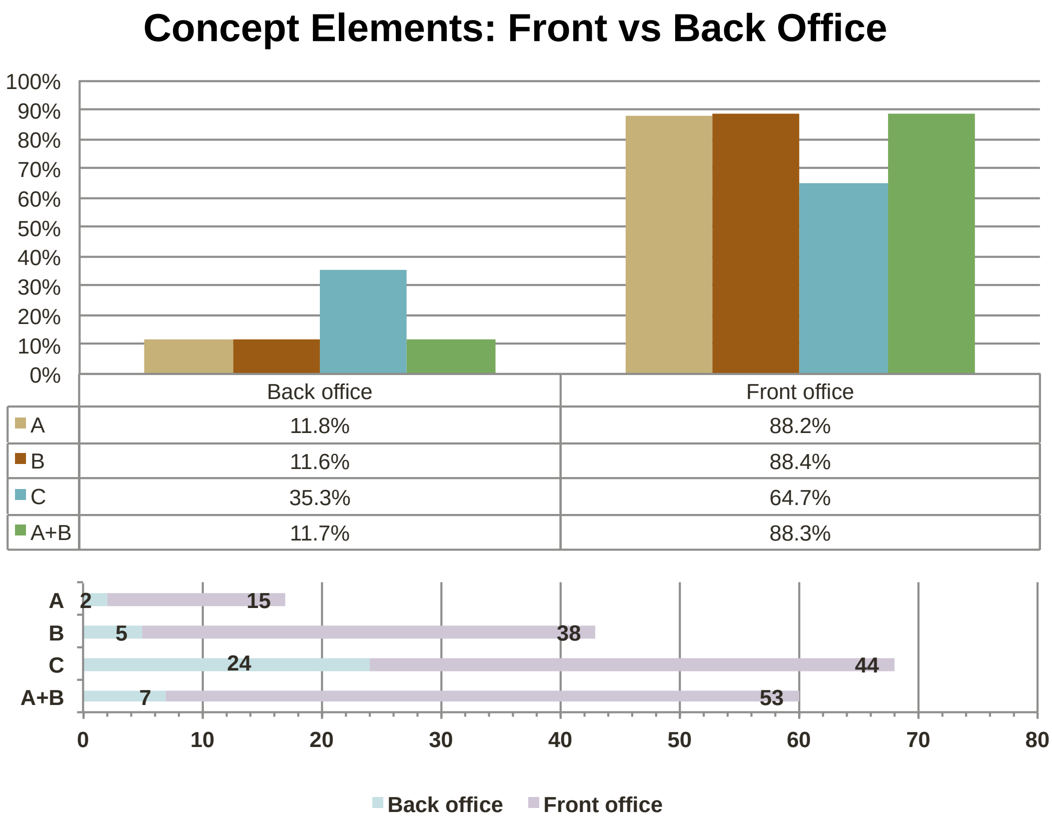


	No Collaboration	External C.	Customer C.	External & Customer C.	Internal C.
A	58.8%	17.6%	11.8%	5.9%	5.9%
B	58.1%	9.3%	20.9%	4.7%	7.0%
C	32.8%	44.8%	20.9%	1.5%	0.0%
A+B	58.3%	11.7%	18.3%	5.0%	6.7%

Figure 51 #Efficacy: The amount of PSS CE including a type of collaboration

Looking into collaboration between the stakeholders mentioned in the PSS-CE (Figure 51) there is a clear tendency that close to 60% in WA and WB has no collaboration, whereas in WC only 30% has no collaboration. PSS-CE including external collaboration is 45% in WC compared to 12% in W(A+B). This might indicate that when bringing together the companies, it increases the focus on external collaboration and hereby results in an increased number of PSS-CE where new relations with a focus on collaboration are a part of the PSS-CE.

Distinguishing the PSS-CE in back-office and front-office illustrates a great difference between WC and WA and WB (Figure 52). In WC more than 35% of the PSS-CE were back-office, compared to only little less than 12% in WA and WB. Specific 24 PSS-CE in WC compared to 5 and 2 PSS-CE in WA and WB. This indicates that bringing together the companies increases the conceptualisation of network concept elements, which includes consideration on back-office perspectives. The companies can be argued to focus better on the efficacy – the constellation of the network which is not directly perceived by the customer. It can indicate that the support tested makes it possible for the companies to co-develop new stakeholder relations to improve their position.



	Back office	Front office
A	11.8%	88.2%
B	11.6%	88.4%
C	35.3%	64.7%
A+B	11.7%	88.3%

Figure 52: #Efficacy: All PSS-CE split in Back-office or Front-office considerations

An example below illustrates a PSS-CE including back-office perspectives;

- **PSS-CE #94_ Collaboration between suppliers on specific areas of product development:** Collaboration on e.g. emissions. There's a need for collaboration between suppliers to create the synergy

"... I definitely see things we could do together, particular on innovation. Here we have shared interests ... how can we find synergies e.g. by market each other ... TIER II and TIER III solutions ... it might be that we could find energy optimisation possibilities for your boiler systems ... I also know that MAN can find reductions on propeller and maybe s-star solutions ..." [Workshop C – quote from PrimeServ Frederikshavn]

Also, if we look at the total PSS-CE conceptualised (Figure 53); 53% of these were created in WC. This means that many of the PSS-CE is connected to back-office constellations instead of changes directly affecting the customer or end-user.

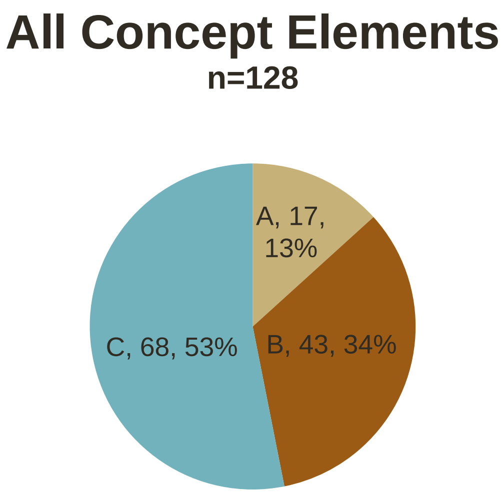
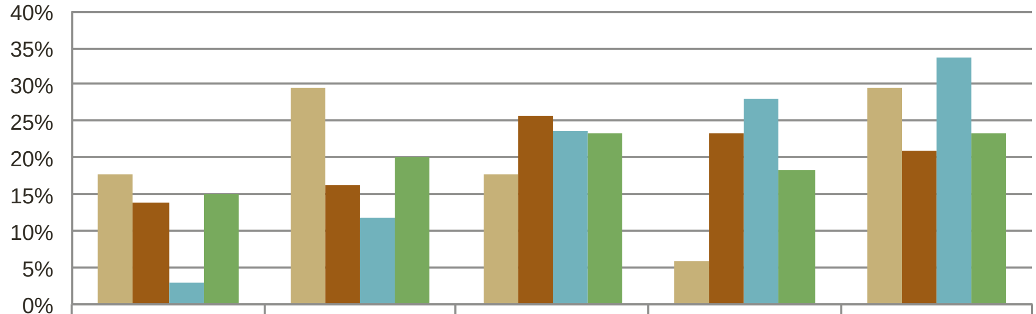


Figure 53: #Efficacy - All concept elements n=128

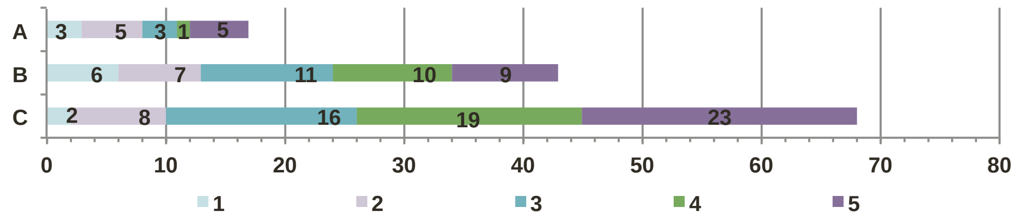
7.2.5 # Feasibility

There is a slight increase in short-term feasibility (Figure 54) in WC, with 61.7% of the PSS-CE on the scale covering 4 and 5, compared to 41.7% in W (A+B). Long-term feasibility is 85% in WC compared to 65% in W (A+B). In WC, the PSS-CE with least feasibility (1) is represented with the fewest concept elements, and onwards to the highest feasibility the number of PSS-CE increases. Bringing the companies together can indicate that the feasibility of the PSS-CEs increases.

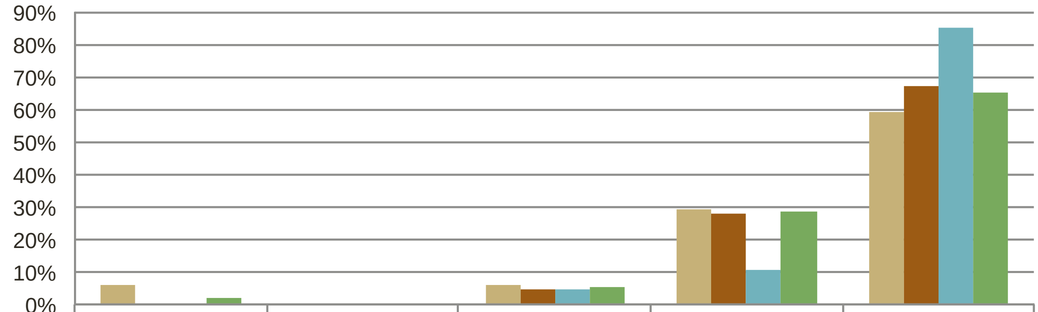
Concept Elements: Short-term Feasibility



	1 - Least Feasible	2	3	4	5 - Most Feasible
A	17.65%	29.41%	17.65%	5.88%	29.41%
B	13.95%	16.28%	25.58%	23.26%	20.93%
C	2.94%	11.76%	23.53%	27.94%	33.82%
A+B	15.00%	20.00%	23.33%	18.33%	23.33%



Concept Elements: Long-term Feasibility



	1 - Least Feasible	2	3	4	5 - Most Feasible
A	6%	0%	6%	29%	59%
B	0%	0%	5%	28%	67%
C	0%	0%	4%	10%	85%
A+B	2%	0%	5%	28%	65%

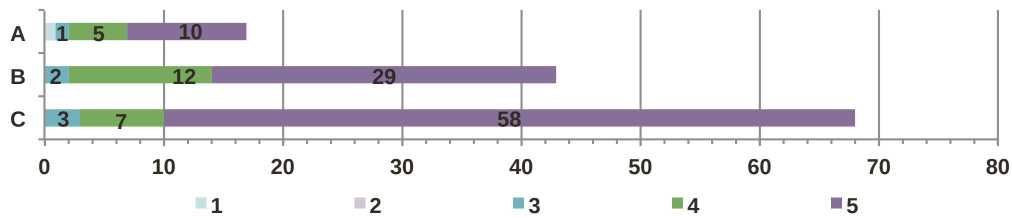


Figure 54 #Feasibility: Short-term and Long-term

7.2.6 Cross analysis

A set of cross analysis has also been conducted, all the cross-analysis is marked at Figure 55 wherefrom a set of six cross-analyses were identified to be presented and discussed, to further detail the findings. The measure focused on efficacy which holds the most detailed perspectives on the ecosystem brought key results, these will through the cross analyses be elaborated in this section.

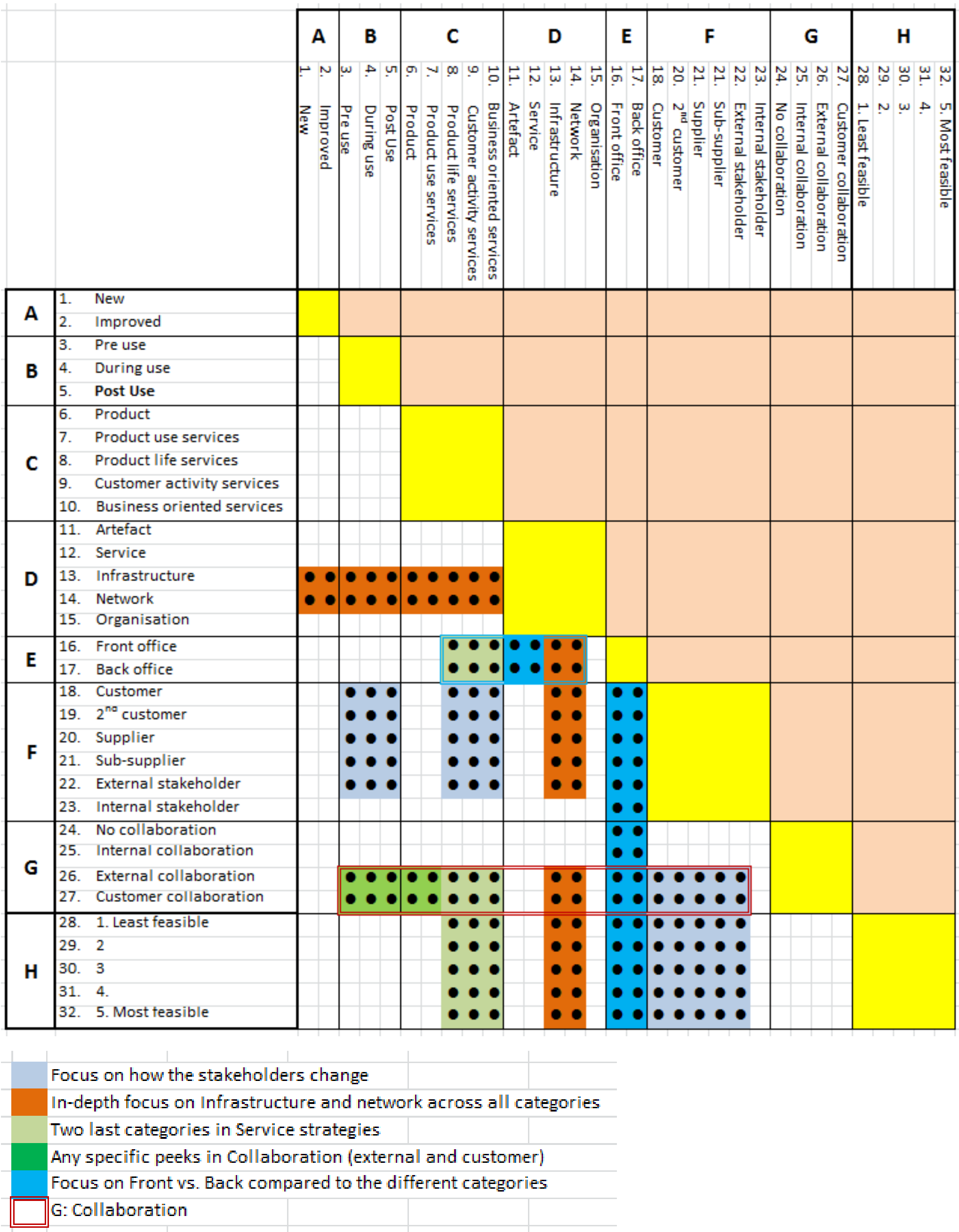


Figure 55: #Cross analysis overview. Throughout the six cross-analyses in this section, the capital letters will guide the focus for the analysis

Cross analysis 1: Back-office PSS-CE: what characterised these? Were they particularly focused on collaboration, including unique stakeholders? (Across categorisations within the same measure E vs. F & G)

The Back-office PSS-CE in WC was significantly more detailed in characteristics than WB and WA (Figure 57). Back-office PSS-CE at WA and WB were focused on internal stakeholders, as can be seen in Figure 56. Furthermore, at WC 18 of 24 PSS-CE with focus on back-office included external collaboration, compared to workshop A and B that had no external collaboration. Furthermore, at WC more than 50% of the stakeholders included in Back-office PSS-CEs were suppliers, compared to none in WA and WB. Therefore it can be concluded that back-office collaboration between the suppliers were increase by co-development activities.

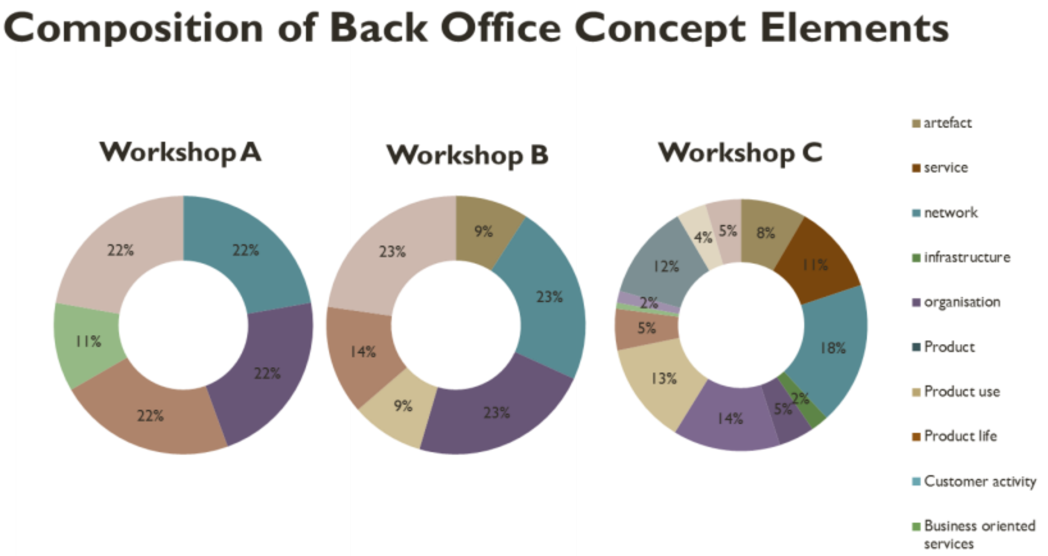
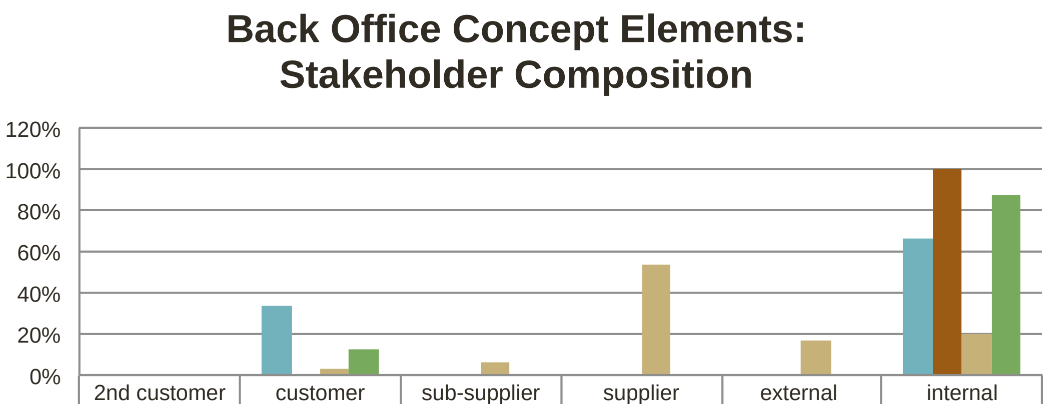


Figure 57 # Cross analysis 1: Back-office PSS CE and their characteristics across all three workshops



	2nd customer	customer	sub-supplier	supplier	external	internal
A	0%	33%	0%	0%	0%	67%
B	0%	0%	0%	0%	0%	100%
C	0%	3%	7%	53%	17%	20%
A+B	0%	13%	0%	0%	0%	88%

Figure 56 #Cross analysis 1: The PSS-CE focused at Back-office activities inclusion of stakeholders

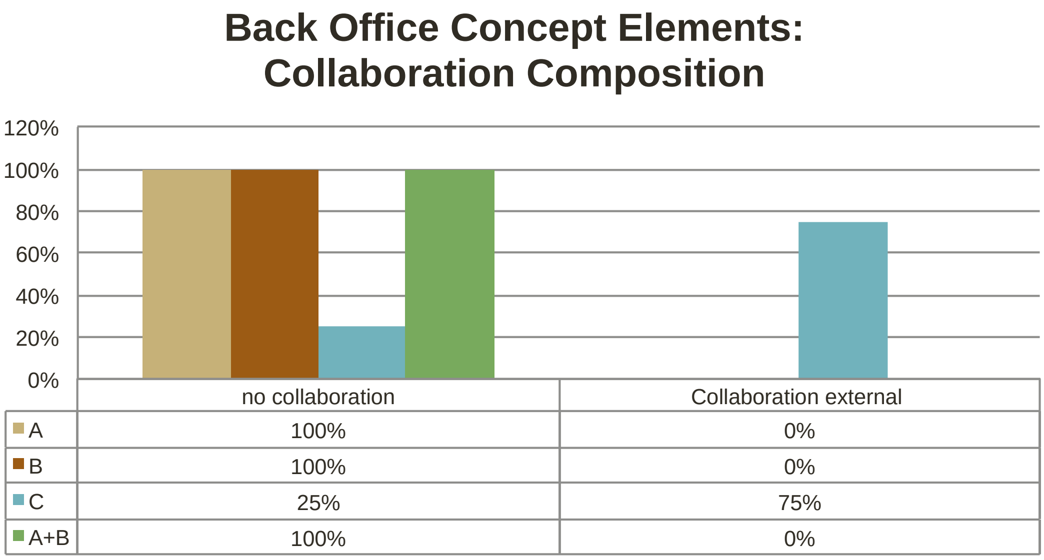
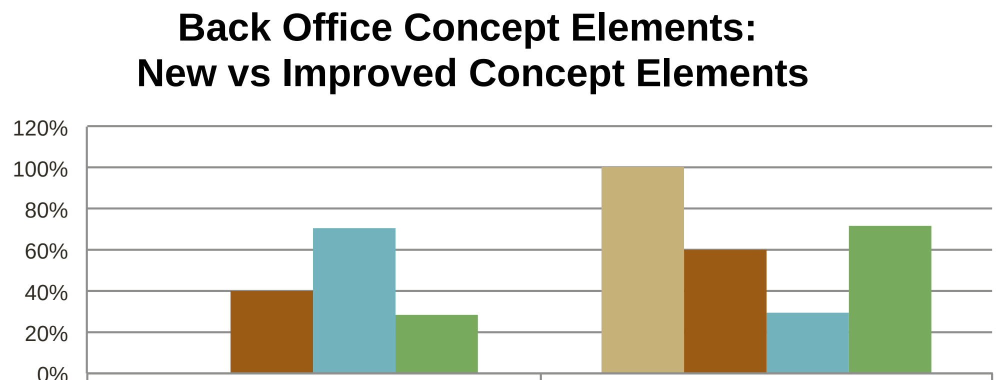


Figure 58: #Cross analysis 1: Back-office PSS-CE and their focus on collaboration

At WC where 35% (Figure 52) were concerning back-office PSS-CE, 75% of these were focused at collaboration (Figure 58). This further indicates that not only is the Back-office PSS-CE increased in WC, they are also including i) nearly 60% of the stakeholders mentioned were suppliers and ii) these perspectives include a relationship of collaboration. This indicates that the back-office PSS-CE is increased and that these are furthermore high Efficacy. The co-development might therefore be increasing back-office PSS-CE with focus on collaboration between suppliers.

Cross analysis 2: The increase in back-office PSS-CE is this based on new PSS-CE or improvements of existing elements? And were they feasible? (E vs. A + E vs. H)

At WC, 71% of the back-office PSS-CE's were new compared to W(A+B) with only 29% (Figure 60). Furthermore 50% of the PSS-CE Back-office was categorized as most feasible, with none categorized as least feasible (Figure 59). This indicates that the PSS-CE with great PSS-CE characteristics, with collaboration and inclusion of suppliers are also feasible.



	new	improved
WA:B	0%	100%
WB:B	40%	60%
WC:B	71%	29%
W(A+B):B	29%	71%

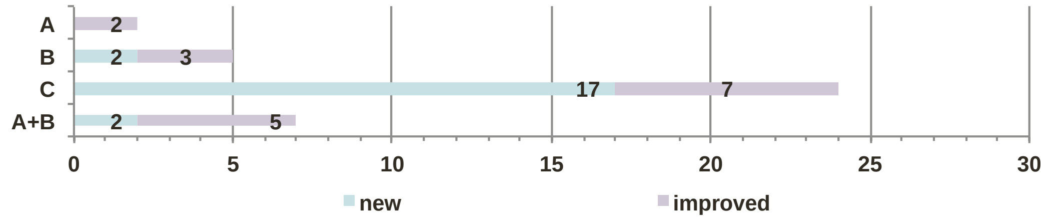
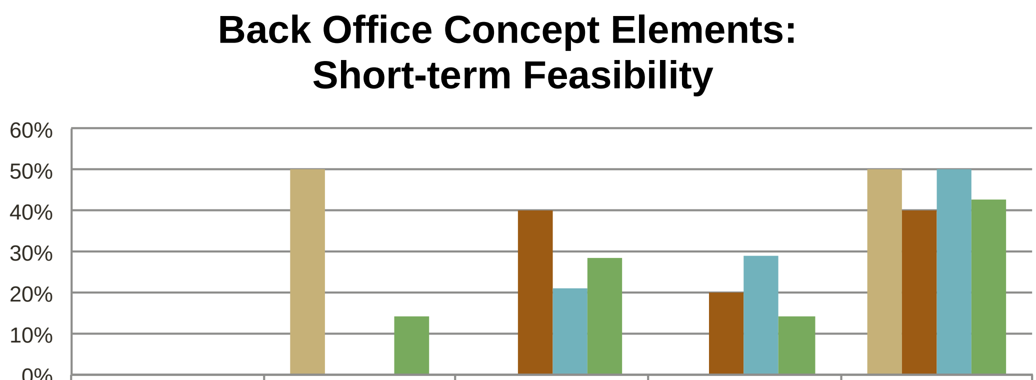


Figure 60 #Cross analysis 2: Of the Back-office PSS-CE how is the split between new and improved PSS-CE



	1 - Least Feasible	2	3	4	5 - Most Feasible
A	0%	50%	0%	0%	50%
B	0%	0%	40%	20%	40%
C	0%	0%	21%	29%	50%
A+B	0%	14%	29%	14%	43%

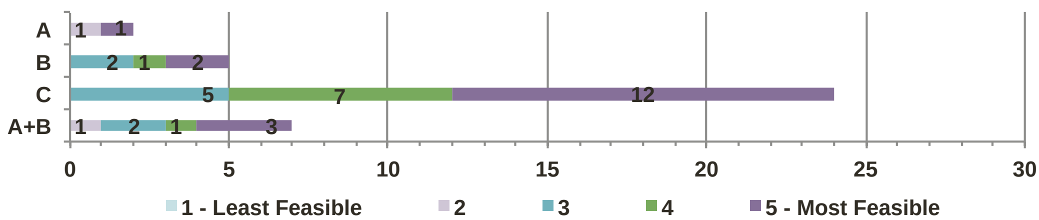
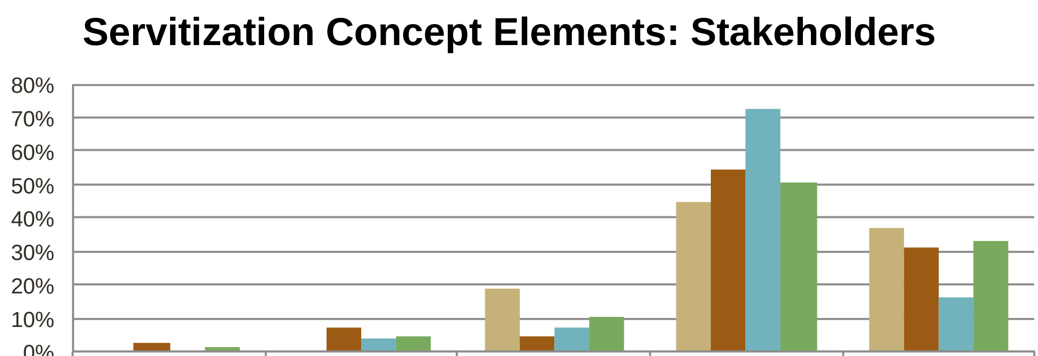


Figure 59 #Cross analysis 2: Back-office PSS CE and the spread on a Short-term feasibility scale

Cross analysis 3: **at WC it has above been stated that the workshop had a peak in the suppliers and external collaboration, where these PSS-CE unique in terms of their position on the service continuum or the coverage of User Activity Cycle? (E,F,G vs. D + E,F,G vs. B)**

The intensity of stakeholders included in PSS-CEs increases in the last three categories across all workshops (Figure 61). WC has the lowest number of stakeholders connected to Business-oriented services with 16% compared to 33% in W(A+B). Business-oriented services are categorised as business activities merged or taken over by the suppliers. As these are indeed front-office activities which might represent competitive elements as they are the channel to the customer, this might explain the unfortunately drop in WC. At Customer activity services, WC peaks with the highest amount of stakeholders at 73%, when looking specifically at suppliers (Figure 62). The reason for this can be argued to that Customer Activity Services are more suitable for co-development and that the support tool might have had an influence on this.



	Product	Product use	Product life	Customer activity	Business oriented services
A	0%	0%	19%	44%	37%
B	2%	7%	5%	55%	31%
C	0%	4%	7%	73%	16%
A+B	1%	4%	10%	51%	33%

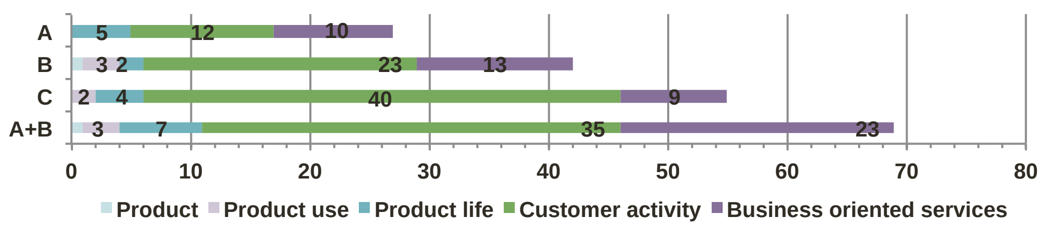
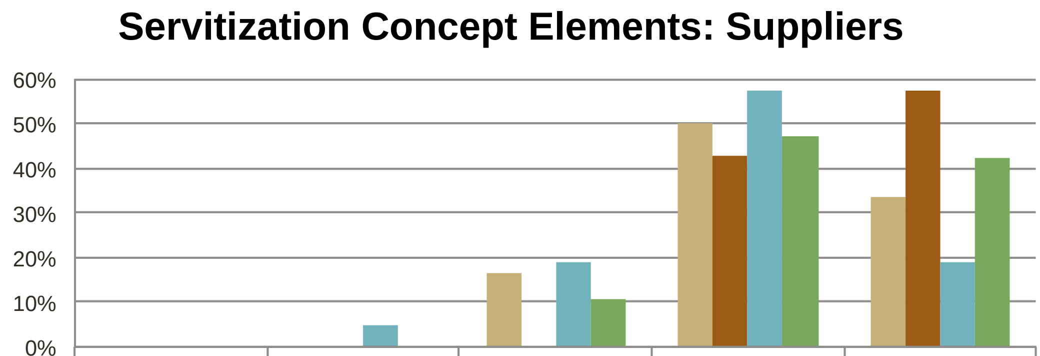


Figure 61 #Cross analysis 3: The stakeholders spread on the Service continuum



	Product	Product use	Product life	Customer activity	Business oriented services
A	0%	0%	17%	50%	33%
B	0%	0%	0%	43%	57%
C	0%	5%	19%	57%	19%
A+B	0%	0%	11%	47%	42%

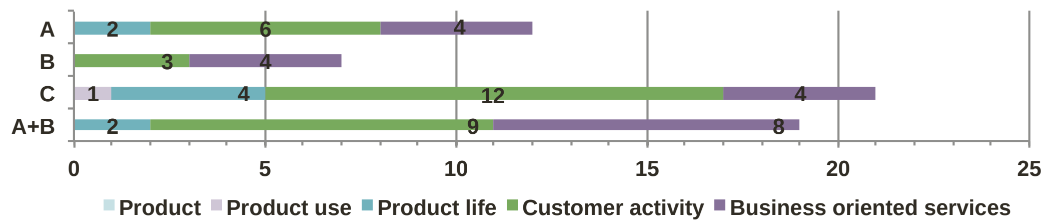


Figure 62 #Cross analysis 3: The suppliers spread on the service continuum

At WC only two PSS-CE were focused at the service category product-life services, which both had a characteristic of collaboration between the suppliers.

Cross analysis 4: The low level of 'no collaboration' in WC; did the PSS-CE carry any unique characteristics? (G24 vs. all)

Most of the PSS-CE with no collaboration was front-office focusing on the service strategy 'Customer activity services'. 12 of 21 PSS-CE included an internal stakeholder on the description. As mentioned previously the drop in no collaboration, may be caused by the fact that the companies at WA and WB were concentrating on internal new structures.

Cross analysis 5: New and approved vs. efficacy - Bringing the companies together increased the level of stakeholders, collaboration level, and back-office focus, but were these PSS CE new or improved? (A vs. E,F,G)

A unique focus at WC and all the PSS-CE which could be measured by the 'efficacy' - were they merely just improvements made to existing offerings or constellations, or were they representing new constellations? Figure 63 indicate that a majority of the PSS-CE were new. The PSS-CE with customers and supplier perspectives included were mainly new PSS-CE. This could indicate that when brining the companies together the novelty (amount of new PSS-CE) increases. This was one of the main intentions and aims for the support, that the companies jointly could develop feasible and novel new network constellations.

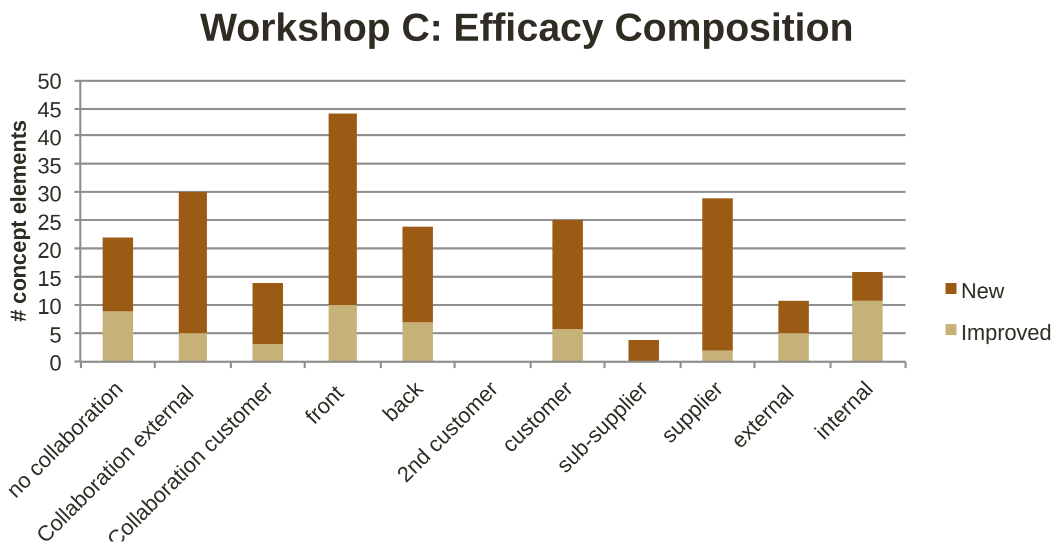


Figure 63 #Cross analysis 5: Workshop C and PSS CE efficacy - including the split of these in new and improved PSS CE

Cross analysis 6: Including a specific cross analysis, looking at the two service strategies, customer services and business services how do they cover the PSS framework (C vs. D)

Is the PSS-CE within the service strategies; Customer and business activity services described using network characteristics? As there were no big changes between the workshops in quantity, a difference might be found in the characteristics connected to each PSS-CE. Figure 64 illustrates that there was no change in efficacy when looking only at these two service strategies. Therefore the coverage of the PSS framework is not alone detailing whether WC made an improvement in network considerations.

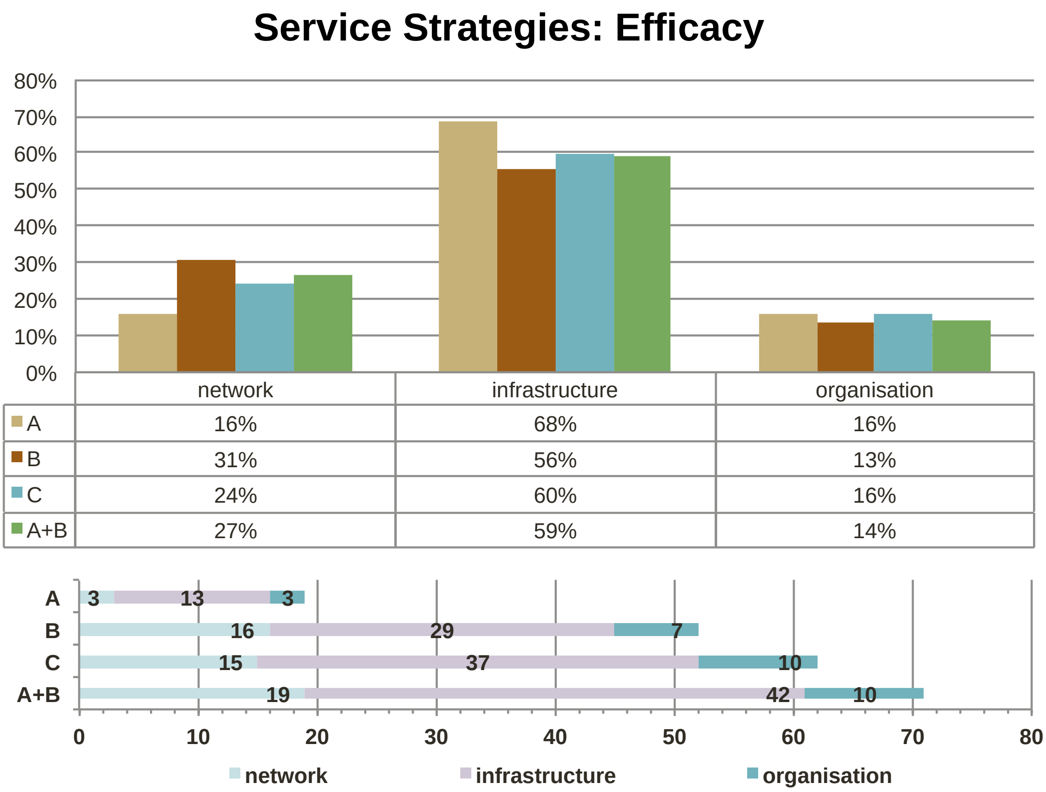


Figure 64 #Cross analysis 6: Service continuum 'representing here a specific focus on the two service strategies; customer activity services and business activity services, and their coverage of the PSS framework.

7.2.7 Synthesis findings

Based on the above analytical generalisation process, a few unique findings will be empathised and summarised in this section.

An increase of efficacy was observed in WC, which were characterised by: i) an increase of back-office relations; and ii) an integration of new relationships compared to WA and WB. None of these compromised the level of servitisation, or their feasibility. A similar increase in the use of the PSS framework dimensions covering network and infrastructure perspectives was not observed.

Furthermore, an increase in PSS-CE covering customer services and business oriented services, were not observed in WC. This increase was not expected, but it illustrates that the focus in WC were on network perspectives, and not an increased service level. The support does not compromise the servitisation nor increase it. Across the workshops the focus was on two of the service strategies of the service continuum; the customer services and business services. The two most commonly used PSS framework dimensions were network and service, and the majority of the PSS-CE included two or three elements.

7.3 Summary

This chapter has presented the evaluation of the actual support developed, defining what exactly has been investigated, detailing the actual support, and detailing the experiment, the evaluation process. The actual support is a combination of the PEC tool and the PSS conceptualisation framework. The development workshop was designed to investigate a particular focus on the PSS ecosystem perspectives.

The evaluation presented was based on a comparative case study, conducted by involving two case companies in an experiment covering three development workshops, and with one change – namely the collaboration structure. W1 and W2 studied the respective companies separately with a focus on intra-organisational collaboration, and in W3 the two case companies co-developed in an inter-organisational setting.

The PEC was used to select and describe the relationship between the stakeholders, the relationship was therefore detailed using the six PSS Ecosystem Characteristics, and a set of future collaboration scenarios are found and described.

Analytical generalisation is used to evaluate the experiment, using a set of five measures, a set of rules and coding parameters, and applying the new construct the new PSS Concept Element. The analytical generalisation integrates concrete examples with PSS concept elements, in direct quotes from the development workshops. The evaluation indicated that the support had a positive influence on 'efficacy', as an increase in back-office relations were observed, and in general supported an increased focus on the network and infrastructure PSS dimensions.

8.

Discussion & conclusion

8. Discussion and conclusion

This chapter discusses the findings presented in the thesis by scrutinising and relating to existing knowledge in the field. The findings are discussed and reflected upon to point to practical applicability of the developed frameworks and normative tools, and to state the research implications of these. Furthermore, a discussion is raised on the validity of the findings, using Yin's four dimensions for detailing research validity.

8.1 Research validity

Yin (2009) defines a set of different tactics and options for evaluating the research design quality, which has been applied in the process of deciding upon, establishing, and adapting the research design throughout the research project. The four criteria for evaluating research validity—*construct validity, internal validity, external validity, and reliability*—will be guiding elements in this section to secure a thorough evaluation of the research validity as they all need explicit attention. These four criteria are widely used within the field of design research and therefore ease the comparison across research designs and results.

8.1.1 Construct validity

The first criteria to ensure validity described by Yin (2009) is to establish operational measures for the research object under study, which is a process closely integrated with the research design and research questions as these must be aligned to ensure that the questions and their constructs are operational. The research design had a focus on establishing a sound platform of understanding the research object, the industrial foundation, in the descriptive explorative study to ensure *multiple sources of evidence*, data triangulation, theory triangulation, and investigator triangulation were made. Furthermore, the use of methodological triangulation, where several different research methods have been used, has made a platform in which a strong *chain of evidence* has been established as findings are derived from single case studies, surveys, and comparative case studies using experiments. This can also be argued to be a point of weakness in the research design as the complete link between DS1 and DS2 can be argued to be lacking or be described as covering too large research areas to be comparable within a PhD thesis. One can question the focus on PSS offering typology (RQ2) being vital for the focus on collaborative development models (RQ3), but limitations were needed, and therefore not all the support tools developed could be tested. The longitudinal study with the second survey is only partly presented in the thesis and therefore brings a non-transparent usage of the findings from this.

Another way to ensure *construct validity* according to Yin (2009) is by ensuring that a *draft case study report* is reviewed by key informants. These have been of particular focus in this research project, continuously throughout the period of the research project, to present and implement the findings to industry practitioners. An actual *draft report* was presented to all the companies – the confidential 'Maritime analysis report', from which the main results were also later made public and published in Workbook #1 in the PROTEUS workbook series. Confronting, presenting, and getting feedback and discussion on the findings was continuously created by interaction with the industry practitioners, particularly during the action-based research approach to the development of the PSS offerings typology, and in the descriptive study 2 within the single case studies, with the many interviews, not to mention the development workshops in the comparative case study.

The PSS tools developed in this research project was made to disseminate the findings from the research project to industry practitioners and served as a possibility to create a closed feedback loop to the organisations and research scholars. The workbooks, PSS cards, and the PSS configurator were also brought into education in a course at DTU, where they were taught in the engineering design and development approach for product/service-systems.

8.1.2 Internal validity

Internal validity is mostly a criteria used in causal explanatory studies (Yin 2009) where a case study is set up to investigate if 'x' led to 'y'. When applying case studies as a research inquiry, focus should be kept on analytical generalisation. Yin explicitly states that a case study is not a sampling unit but should be selected by its potential to act as a laboratory for new experiments. Therefore, the sample size is not critical for internal validity as the focus is on analytical generalization. The comparative case study was to investigate whether the systematic use of the developed PSS conceptualisation framework and the PEC tool had an influence on the level of integrated PSS ecosystem perspectives. This was controlled by the set-up of an experiment with a set of five measures: *service level; novelty; efficacy; holistic;* and *feasibility* of the PSS concept elements. The analytical generalisation conducted in the chapter 7 was therefore a means to create an analytical generalisation, through scrutinising the PSS Concept elements developed. The (sample size) experiment included a total of 128 concept elements and was analytically investigated through the five measures and a set of 34 categories. The investigation was therefore mainly qualitative.

Furthermore, for internal validity this can be created by carefully choosing the data analysis methods to ensure that it is possible to create the causal relationship and to indicate that that certain conditions lead to other conditions. The tactics of pattern-matching, explanation-building, and time-series analysis can be used for this. In this study, the coding and the rules used for making the analytical generalisation *explanation-building* was used by integrating theoretical constructs from multiple theories.

8.1.3 External validity

Within all case studies in the research project, *external validity* was carefully integrated in the research design, which was continuously maintained throughout the research project, to establish a 'domain' from which the findings can be generalised, to make sure the findings are generalizable beyond the immediate case study. This criterion was one of the main criterions to strengthen, as stated earlier. There is a need for empirical investigation of PSS, with particular use of cross-case testing together with longitudinal empirical investigation and was therefore an integrated element in the research design.

The single case studies with the focus on exploration of the research field, aiming at research clarification and building the PSS offering typology, used a participant action-based research approach to describe and prescribe the processes and concepts observed. The interaction with the company cases involved multiple industry practitioners from each organisation, representing various functions at the companies. Within the comparative case study, a deep-dive into the field of study was conducted leveraging the trust that had been built during the previous research stages in a descriptive study to validate the PSS conceptualisation framework and the PSS PEC tool developed. This study involved the two selected case companies in an in-depth interview round, and the three development workshops, by involving multiple departments and various functions in the company representing top management and in-field technicians. Refer to Table 14 for an overview of involved stakeholders.

The focus on a whole industry branch, involving ten companies, which all were suppliers of products and/or services to the maritime industry; all with key customers such as shipyards and shipowners; and with their main offices located in Denmark, made a strong foundation for generalising the results to be applicable for the industry in general. The differences between the companies acted as verification rather than a threat to the validity concerning parameters, such as company size, type of products and services, organisational structure, experience level, etc. The companies also represented different levels of readiness and positions in the transition towards a more integrated product/service-oriented business. Actually, the industrial research case foundation represented companies moving towards *servitising* their business and the opposite *productising* their companies.

8.1.4 Reliability

The last criterion for the research validity to be judged is research *reliability*, which concerns the rigidity of the procedures followed and documented during the research project. Within action-based research, this is the most difficult parameter to judge and is also why the research is not "validated," but rather it is evaluated. The design research approach has been following an action-based research approach, where an aim is to improve and acquire knowledge of the real-world situation simultaneously, which means that replicability is not possible. Checkland and Holwell (1998) point towards the notion of *recoverability* in place of replicability, whereby it is possible to 'repeat' the research design, where a complete transparency in the research procedures has been provided. As mentioned above, triangulation in both data sources and investigators has been used widely in the research project, which made it vital to describe the methods and keep them rigorous. Each research stage has been described and detailed in-depth in section 3.2 which has incorporated as many research steps as possible to make the research operational. Being part of a larger research team, investigator triangulation was a continuously inherent part of all activities and procedures to be documented and to make sure these were explicit and easy to understand. This is why both a case study protocol and a case study database have been used. The methods used for documentation, which made use of a very systematic document database and material archive. Furthermore, all data created by interacting with the industry practitioners was kept in its raw format to bring reliability of all the data and its later interpretations.

8.1.5 Research limitations

During the research project's different research phases, limitations occurred, which influenced the research activities and the research results. Some of the limitations more directly influenced the research validity, others concerned the possibilities for research directions and scale of activities. All of the limitations included in this section influenced the research project's final results, but not all can be explicitly detailed and described to uncover the actual impact they had.

The main limitations of the research presented in this report can be summarised as follows:

- The evaluation of the comparative study represents a few obstacles, as the coding in itself and the PSS-CE are difficult to identify and to interpret correctly, and there no investigator triangulation was carried out for the evaluation, both of which have remarkable influence on the evaluation of the experiment.
- The comparative study was structured by a set of three development workshops. The support to be evaluated was used by

the author to: i) select and analyse a set of collaboration scenarios between the companies; ii) in preparing and designing the development workshop; and iii) using during the development workshop. What was evaluated was therefore both the activities of the facilitator (author) and the participants, which influences the evaluation.

- The evaluation is based on a single experiment. A second comparative study, or co-development workshop would have brought deeper insight into whether the support developed had an effect.
- The research design included two descriptive studies, which could have been better interlinked. The longitudinal study was chosen not to be presented in the thesis, as it is not possible to claim that the research activities led to the changes in the companies.
- Neither the PSS Cards, nor the PSS Configurator, nor the PEC Tool were evaluated by industry practitioners in a systematic way, due to time constraints.
- The PSS offering typology is based on the action research involving only companies from the PROTEUS consortium, meaning that it is therefore not representative of best-practice PSS offerings.
- Two of the developed support tools – The PSS cards and the PSS configurator – were not tested rigorously. They were not included in the comparative case study, as the focus was on evaluating the PEC tool.

8.2 Discussion of findings in relation to existing knowledge

This research project has contributed to two main streams of knowledge by: i) presenting a large literature review on service strategies, service typologies, and transition frameworks resulting in an industry specific PS-typology and a synthesis of a whole industry covering ten companies within the maritime industry; ii) investigating conceptualisation and the ecosystem dimension of PSS and derived at a set of PSS ecosystem characteristics and a conceptualisation tool Product/Service-ecosystem characteristic (PEC); and iii) developing several tools, one of which has been tested through a comparative case study. What characterises the research approach applied in this research project is the triangulation between theory and work-practice to create empirical insights, with the main approach of a strong participatory lead and action-based research.

The research within this project and also within the PROTEUS innovation consortium, contributes to and is in continuation of the line of PSS- and Product Development research work produced by the Section of

Engineering Design & Product Development, within the Department of Mechanical Engineering, at the Technical University of Denmark.

8.2.1 PSS offering typology

The PSS offering typology is built through a true iterative action-based research approach and research design. A thorough literature review has made a PSS offering typology of much relevance to the industry. The point of departure for this PSS offering typology was to create a large literature review from which an existing service strategy framework could be adapted to continue a generic PSS offering typology for the maritime industry. The selected framework was that of Tan et al. (2009). This framework was built based on the service strategies possible when transitioning towards a more service-oriented business, and many methods were found which were grouped into the service strategies presented in the framework. Detailed earlier, this framework was suitable to adapt and continue the service offering listed. Furthermore, this framework needed empirical validation. The development of the typology in this research project was among many reviewed frameworks based on the characteristics listed in the morphological scheme presented by (Tan 2010). Here it became apparent that characteristics within this morphological scheme and other PSS characteristics were combined to constitute the PSS offerings in the maritime industry. Therefore, it also became apparent that for industry practitioners to relate to the typologies they cannot be solely theoretical frameworks. They need to be combined with industry specific typologies, or at least have more industrial references, and not be split into 'atoms' as is the case with PSS characteristics. They do not refer to a phenomenon or activity on their own, which might be the case for more engineering morphological frameworks. Also the Offer Portfolio developed by Matzen (2009) brought a 'typology' – which was divided into three main elements: Agreements; Activities; and Products. This portfolio was generic and represented a view of the companies' capabilities and product portfolio. As mentioned previously, these categories are theoretical and the companies were observed to mix the elements when contextualising their offerings.

Furthermore, two particular studies are worth mentioning, as these have been conducted as large empirical research studies: the study by (Neely 2007) and (Baines et al. 2010). These two studies were able to describe industry readiness and current state of transition to an integrated product/service-oriented business. Baines et al. (2010) charted the financial structure of each of the service offerings found at all the companies, which was aimed at in this research project as well, but as the industry was immature (from a purely servitisation perspective), it was not possible for the companies to separate all the service activities from the product offerings. Furthermore, the interviewees disagreed on the financial part of the offerings, which therefore resulted in this layer of the charting being left out of the final presentation of the findings in chapter 5.3.

None of the mentioned frameworks of service classification provided a detailed description of the services within the frameworks, which was one of the aims with the PSS offering typology within this research study. Also, none of the results were presented with company-specific chartings as is the case with this research. This is why in the findings of this project all the chartings can be traced back to a unique company and also this can serve for additional analysis of the findings, as the data collected are in their original format.

Critique of the PSS offering typology developed in this research project can be placed on the lack of state-of-the-art practice in PSS, as the industry is in a transition the PSS offering typology might in near future lose its applicability as it will not match the state of the industry. However, the research approach to build the PSS offering typology was to analyse and synthesis the industry's current position in the transition and to provide the companies with a language to use when describing and detailing the offerings already existing in the industry, in order to encourage knowledge sharing and the possibility for easy transfer of services across companies.

Another interesting approach to identify and assess value-in-use has been presented by Macdonald et al. (2011). Here a focus was not solely on the offerings present or possible from the supplier 'maintenance service provider', but from the customers' use process. The value-in-use presented in this work is therefore derived from interviews among customers. The approach in this research project has included only the offerings found already in the companies in PROTEUS, but could have benefitted strongly from a combined approach, where customers had been involved directly as well. Furthermore, this approach could act as assessing value-in-use as a detailed approach for defining quality of the offerings within the maritime industry and thereby act as a strong approach for testing the methodology's generic applicability. As the offerings are found in this research to often be a collaborative activity, where the service activity often depends on the level of insight into the system of the customer, or by the processes conducted by the customer, the approach presented by Macdonald et al. (2011), where provider processes and customer processes are involved in defining value-in-use, is in the eyes of this research an indeed interesting and suitable approach.

Also, after this research project had finished, during the writing process, multiple articles have arisen, which focus on this topic. Raddats and Kowalkowski (2014) work on a re-conceptualisation of Manufacturers Service Strategies. They present an in-depth literature review and derive a set of three main service strategies: product-attached services; operations services on own products; and vendor independent operations services.

They aim for a generic typology of manufacturer's service strategies using a survey of 145 B2B manufactures in the UK. These service strategies are used to define behavioural characteristics in manufacturing companies adopting these service strategies. From this large empirical study, they found three classifications of the manufacturers: Service doubters; Service pragmatists; and Service enthusiasts. Relating this work to the PSS offering typology in this research project, again the services found are not operationalise merely a theoretical matrix, but hold interesting details from the empirical study and literature review.

A study conducted by Gaiardelli et al. (2013) presents a study with the exact same aim as the one connected to this research project's DS1, "*… a more detailed understanding of the product/service types might advance the collective knowledge to assists companies that are considering a service strategy …*" This study produces an impressive literature review from which the typology is developed. The development, though, takes point of departure in the well cited framework from Tukker (2004), but broadly integrates many different service strategies and service classifications. The development of the typology is dervied from a theoretical literature review and applies the typology to one company, whereas the typology in this thesis is derived from an action-based research approach with multiple iterations between industry application and literature reviews, resulting in many adjustments of the typology. The empirical industrial foundation covers a whole industry very broadly – and not a single company as within Gaiardelli et al.'s study. The detailed descriptions of the services found in the study of Gaiardelli et al. (2013) hold much rich contextual descriptions and offers important contributions to the research field. The findings from the study compared to the findings from the offerings detailed in this thesis would add an even more rich contextual description and could be the first research step to get closer to a generic typology. The last reflection on the work by Gaiardelli et al. (2013) goes to the novel representation of all the offerings, which is achieved through a matrix, covering: on the one axis, transaction-based to relationship-based offerings; and on the other axis, product-oriented, use-oriented, and result-oriented. This representation technique holds two interesting elements: i) that the author believes that also product related offerings, can be in a relationship-based setting, and also opposite a use-oriented offering can be transaction-based; ii) this representation technique would have been highly interesting to test in the research project presented in this thesis.

8.2.2 PSS conceptualisation framework

The PSS conceptualisation framework used in this research project continues the work made by Adrian Tan, Detlef Matzen, and Oksana Mont. The research project has therefore tested and adapted the existing framework by: i) an empirical case studies in ten maritime companies and an in-depth comparative case study; ii) the framework has been developed and adapted by the literature reviews in this research project.

Introducing the PSS Concept Element brought an extra theoretical construct to emphasise that the PSS conceptualisation framework can consist of fractions of a PSS concept, and this made it possible to analyse qualitatively what kind of PSS concept element was developed during a series of development workshops. Such a detailed study with a comparative case study and an analytical generalisation has not been seen in a research constellation before, with focus on: i) PSS conceptualisation; ii) Ecosystem; and iii) Empirical comparative case study.

8.2.3 PSS ecosystem conceptualisation

The actor network perspective has already been an established perspective in PSS literature (Manzini et al. 2004) and is part of many frameworks describing a PSS. The explicit importance of the ecosystem in PSS is stated in many transitioning frameworks (Martinez et al. 2010; Davies 2004) and conceptualisation frameworks (Mont 2004; Tan 2010; Matzen 2009) as well as elaboration on what changes in PSS when going from a product- to a performance-based company (Stahel and Reday-Mulvey 1981). The more detailed approach of describing the structure of the ecosystem within a PSS has been approached but in a simplistic view that uses only limited characteristics. An example is the work by Baines et al. (2011) and Wise and Baumgartner (1999), which describes the need and possibilities for vertical integration. Martinez et al. (2010) describes the change in interaction from transactional to relational, also detailing a specific characteristics of the ecosystem perspectives in PSS.

The findings based on the research presented in this thesis state the importance of the 'collaborative' ecosystem, which is discussed throughout the thesis as a necessity in the global business landscape, but most importantly to establish and develop a successful PSS. The research project presented in this thesis had a core focus on one dimension of the PSS conceptualisation framework. Compared to many previous research contributions or PhD theses, a holistic view of PSS has been taken, a merely conceptual approach, whereas this research project builds on this and brings a more intensive focus on the ecosystem of a PSS. The development of a set of PSS ecosystem characteristics provides a holistic view to approach the importance and the complexities of the PSS ecosystem. Instead of single characteristics as mentioned above, the findings in this research project point towards a need for a strengthened mindset and unique language to describe the ecosystem in a PSS. From these characteristics, many design tools can be made, of which a set is presented in this thesis. In this sense, the PSS ecosystem characteristics can be seen as a theoretical reference framework on which new tools can be developed to broadly integrate the different characteristics of the PSS ecosystem.

A few specific research contributions will be compared to the findings in this research project

Solution Oriented Partnerships Methodological Framework (SOPMF) presented by Manzini et al. (2004) is a reference framework for building new PSS tools with a focus on new relations within the ecosystem. The framework presents a matrix with twelve different key actions. If the PSS ecosystem characteristics presented in this thesis should be placed in this framework, they could be argued to cross all the key action points as an inherent mental mindset creating awareness of the 'freedom of design' in connection to the PSS ecosystem and the possibilities for new constellations possible to conceptualise and develop a sound ecosystem structure for the PSS Solution. In this sense, the boundary condition developed by McAloone (2011) could be argued to frame the overall development arena of a PSS, whereas the PSS ecosystem characteristics provide a specific view of one of the PSS dimensions and perspectives, namely the ecosystem.

Windahl and Lakemond (2006) present six factors which influence the development and the success and/or failure of a PSS. All these factors except one had a focus on inter-organisational relationship in the ecosystem. They argued that the focus on the organisational structure (intra-organisational relations) and the core focus on the importance of a customer centric organisation needed to be broadened to take into account all the six factors found in their study. Comparing the factors to the characteristics found in this research project, the factors focus primarily on: i) Intensity; ii) Between stakeholders; and iii) Value creation. The factors represent a 'state' or a descriptive situation, like *position in the network.* This corresponds to *Between stakeholders* but with the point of view from a single stakeholder. Another factor mentioned is *the solution's impact on customers core processes*, and this is describing the new relations in terms of how the PSS solution affects or changes the process of the customer by combining two ecosystem characteristics, the 'value creation' and the 'Between stakeholders'. The findings are described by comparing the factors against each other in a matrix, pointing towards a set of managerial implications. The results are primarily theoretical findings, and no normative tools for the industry practitioners have been developed nor tested.

A specific focus on collaborative networks' influence on a company's innovation capability has been presented by (Wallin 2011). Here a set of seven collaboration types was presented as a representation of all "*collaboration competence development possibilities"*, with a core focus on collaboration between different stakeholders intra- and inter-organisational. Therefore, in comparing the findings from this study, the seven collaboration types can be seen as a detailed description of the characteristic "Between stakeholders" found in this thesis, and in this way it can also be argued to be a narrow view of the collaboration competence development possibilities.

A recently completed research project from Cranfield by Cakkol (2013) is entitled *"How does servitisation impact inter-organisational structure and relationship of a truck manufacturer's network?"* The research project has many similar research inquires as in this thesis, though the research method and findings are different. Important to mention is the same approach to the literature foundation, which is structured around two main reviews: i) PSS/Servitisation; and ii) Network paradigm, which is similar to the work presented in this thesis. The network paradigm has a strong focus on marketing and management literature covering inter-organisational relationships (IORs), and therefore also summarising the literature review on defining IORs. To describe IORs in PSS, Cakkol (2013) uses the multi-theoretical framework for studying IORs presented by Cannon and Perreault (1999). Bastl et al. (2012) also made a similar approach to study IORs. The original framework of Cannon and Perreault has five different relationship connectors (or later referred to as relationship dimensions): *Information exchange, operational linkages, Legal bonds, Cooperative norms*, and *Buyer and seller adaptation*. The main findings from Cakkol (2013) are the identification of two extra relationship attributes: *Service orientation* and *long-term relationships*. A total set of sub-attributes are presented, found by the use of a single case study of MAN Truck & Bus, where the network structure of three different offerings are investigated by detailing customer imperatives, network structure, and relationship focus. The relationship attributes can be compared to the ecosystem characteristics presented in this thesis, but they serve different goals. The attributes are assigned to different types of offerings, and in this way they are static and serve as a final categorisation and description of the offering in terms of ecosystem structure, whereas the PSS ecosystem characteristics in this thesis are meant as a way to describe and conceptualise the PSS ecosystem.

Comparing the relationship attributes found by Cakkol (2013) to the study of customer value-in-use by Martinez et al. (2011b), the attributes serve as a retrospective study of the 'values' connected to a relationship, whereas the value-in-use analysis uses the receiver of the solutions, the customer, to define a set of specific not generic set of perceived values. This allows the manufacturing company to decide actively on possibilities to change network structure by, e.g., outsourcing activities or partnering to assure important activities not present already meet the values required from the customer.

Ruiz and Maier (2012) present a framework to detail "*aspects characterising co-design*". These aspects integrated are much similar to the characteristics found in this thesis, though a difference is in the focus as the aim for the characteristics found in this thesis was to support the change from a product-oriented business to an integrated product/service-oriented business by detailing the need for a holistic network approach and a collaborative nature of the operation and development of not a product but a PSS. The characteristics found and presented in their framework detail the aspects of co-design. They were aiming at consolidating knowledge around co-design by combining the field of Engineering Design with Technology and Innovation Management. An extensive study was carried out to do so, covering a total of 1,429 papers and employing a network analysis approach using Touchgraph to identify clusters of unique keywords and theoretical constructs to integrate into a set of final co-design characteristics.

The PSS PEC Tool and its different use scenarios presented in chapter 6 can be compared to many existing tools within service design and stakeholder network modelling. Though also distinct from existing stakeholder network mappings and analysis procedures, the characteristics serve as an opportunity to bring a comprehensive mental mindset and shared understanding of how to understand and describe the ecosystem constituting a PSS.

8.3 Key findings

The research project presented in this thesis has followed a research design using action-research as a key element. The first study presented the PSS offering typology followed by an industry analysis using the typology. This was developed through an iterative approach by in-field activities and a literature review. The PSS ecosystem characteristics were developed by a purely qualitative literature review and tested by a participatory research design setting up a comparative case study by three distinct development workshops. This section elaborates on the findings by presenting each research questions and the contributions to each of these.

Research Question 1: Through what terms and models can PSS offerings be described in order to support their successful synthesis?

Using a framework for PSS development strategies, where PSS offerings can be positioned on a continuum – at one end supporting the product and the other end supporting the customer – strengthens the understanding of the PSS offerings. Combining multiple PSS characteristics within a single PSS offering supports the PSS designer's ability to comprehend and relate the offerings easily to a contextual setting. Furthermore, developing a detailed description of each of the service offerings was vital because this supports the process to make the service-logic operational for industry practitioners. The framework chosen presents five different service development strategies, and the offerings found, developed, and detailed cover a set of 48 offerings. A set of icons were assigned to each offering to further support the easy comprehension of the many offerings found the industry. The cross-disciplinary literature review revealed many approaches for describing offerings in PSS, including lists, matrices, transitioning frameworks, continuums, meta-clusters, categories, typologies, industry examples, with many more. The key element across the different representation techniques was that they were mostly presented using two or more PSS characteristics, all presenting different suggestions for categories and typologies not being consistent. Furthermore, a key finding was that the research approach was lacking use of cross-case and in general empirical testing. Based on this, the approach for developing a PSS offering typology was created based on a strong participatory-research approach where multiple iterations were made between literature and industry.

Research Question 2: How can a PSS conceptualisation activity take advantage of a PSS offerings typology in the creation of PSS solutions?

A need for tools to support collaborative design activities within PSS development exist as the development activity: i) spans multiple departments in the organisation; ii) is inter-organisational to include, suppliers, customers, etc.; and iii) the PSS concept must be communicated on an abstract form to aid collaborative conceptualisation. The PSS offering typology was developed into a set of PSS tools guided by the taxonomic notion of overview and the principles of design models to support communication between multiple stakeholders for the purpose of joint conceptualisation. The PSS configurator represents a design tool supporting the PSS designer in bringing together an offering package by an in-built logic supporting the transparency of the dependencies between the offerings, whereas the PSS cards support a free flow of thinking with point of departure in creativity cards, where the tactile element of the method brings a value. Furthermore, the PSS methodological reference framework developed during the PRTOEUS consortium serves as a reference for which tool to develop or use in the different PSS development stages to ensure coverage of all PSS dimensions.

Research Question 3: How can a PSS conceptualisation activity allow an inherent network approach for co-development of the PSS-design?

The PSS Dimension—the ecosystem—perspectives holds invaluable insights and design possibilities of high importance when conducting PSS conceptualisation. A thorough understanding of the importance of these design perspectives within the PSS ecosystem dimension must be brought to the PSS developer and be an inherent element in all PSS development stages and conceptualisation activities. A design method can be seen as a mental mindset, a structured way of thinking. Like the 'PSS boundary conditions', it is a guiding element in which new design freedom a PSS brings, the development of a set of ecosystem characteristics was found to be a key element in any further development of PSS tools to integrate the perspectives and all the opportunities within the dimension of the ecosystem. It also became apparent in the literature study, which was conducted by a cross-disciplinary approach, that inconsistency in network typologies existed. A total set of six PSS ecosystem characteristics (PEC) were found in a pattern-matching approach during the literature review, and these were described and detailed and further developed into a set of scenarios of how to include these many perspectives in PSS conceptualisation.

A comparative case study was set up as an experiment and illustrated the importance of multiple stakeholders taking part in a conceptualisation activity. What was found through a research evaluation using the approach of 'analytical generalisation' was that certain ecosystem perspectives were enhanced during the co-development workshop. The conceptualisation activity was designed using the PEC and the PSS conceptualisation framework. A key finding was that the back-office network constellations increased significantly when the two companies were co-developing PSS concepts. This indicates that a network constellation can be designed and when bringing together stakeholders from the ecosystem might open up the solutions space of the PSS.

8.4 Core research contributions

The research project presented in this thesis contributes to the knowledge within the research fields of PSS and Engineering Design and Product Development. In particular, seven contributions can be highlighted as core research contributions to the field:

- *An industry specific PSS offering typology*; development of a PSS offering typology using an action-based research approach with an industrial research foundation of ten company cases from within the same industry branch – namely that of the Danish maritime industry. A set of 48 PSS offerings has been presented by a detailed description and graphic illustration of each.
- *Charting a whole industry current level of PSS offerings*; an in-depth synthesis of the industry has been presented. Using the PSS offering typology to present their current state of servitisation in terms of their current 'value propositions' offered to their customers.
- *Provision of three new normative PSS tools* allows a collective design activity in achieving a strengthen knowledge foundation upon which to base synthesis and conceptualisation of new PSS offerings:

1) PSS Cards consist of a set of 48 physical cards with descriptions and graphics of the PSS offerings; 2) the PSS configurator providing an online platform with an in-built logic to support the developer in designing a PSS offering package; and 3) the PEC tool – to support a inherent network approach in any PSS development phase.

- *PSS Ecosystem Characteristics (PEC)*; a theoretical cross-disciplinary perspective on the PSS dimension – the ecosystem perspectives – to consolidate knowledge around the importance of and complexity inherent in the ecosystem surrounding and constituting a PSS. The PSS ecosystem characteristics will strengthen the understanding of the PSS ecosystem perspectives and bring new detailed levels to PSS thinking. The characteristics can be used as a theoretical platform for selecting or developing new PSS tools to use to integrate the ecosystem perspectives into PSS development.

- *Empirical testing of a PSS conceptualisation framework and PEC;* Implementing an existing PSS conceptualisation framework and the PEC to design a conceptualisation activity wherein a strong focus on the ecosystem perspectives would guide the co-development activity.

- *Developed and implemented a new theoretical PSS construct, the PSS Concept Element (PSS CE)*; PSS conceptualisation consists of iterative activities spanning the PSS dimensions and the different development stages. Crossing all phases, fragments (PSS CE) of a PSS concept is conceptualised, from which a PSS concept can be created and brought to a level to allow evaluation. The PSS CE brings an opportunity for detailed analysis on the outcome of a conceptualisation activity, which has been demonstrated in this thesis.

- *Systematic analysis of an entire industry branch, disseminated to industry;* A particular contribution has been made by the author to Workbook #1: *Maritime Branch Analysis; Workbook* #2: *PSS Case Book*; and Workbook #6: *PSS Partnerships*. *PROTEUS Workbook Series;* During the research project a particular focus was on disseminating results to industry continuously throughout the research project, which was also achieved by providing the normative PSS tools.

8.5 Future research

During the research project, which followed the chosen research approach highlighted earlier in the thesis, certain areas appeared which were interesting to pursue, but which have not been included in this thesis. There is therefore a large potential for future research pathways, based on the journey and the findings presented in this thesis. Especially during the descriptive and prescriptive studies, and in the final research results, areas of interest for future research are revealed and indicated.

In general, the suggestion for future work will be to continue the research inquiry through an action-research approach where new normative tools are developed and tested in close collaboration with industry. Furthermore, the research method of cross-case use is suggested as this is still under represented in literature. Also the limitations presented and discussed in sections 8.1.1 - 8.1.5 constitute potential future research areas.

Future work based on the research contributions presented in this thesis:

- *PSS offering typology;* The PSS offering typology can be further developed to also include best-practice cases to fully complete the typology. Conducting a research study to test its empirical generic applicability is also suggested. It is also suggested to make a stronger link between PSS research and the research field of service engineering, with focus on through-life services and "self-healing" services where focus is on design for intelligent and smart self-operating and maintaining systems. The IoT (Internet of Things) and M2M (machine to machine communication) are areas of research that would also be highly valuable to an integral approach for design of new PSS offerings.
- *Empirical testing of the developed PSS tools*; the two PSS tools, PSS cards, and the PSS configurator both need to be empirically tested. A further development of both is suggested with use of case studies where they are tested and adapted.
- *Continue the development of PSS ecosystem characteristics*; the cross-disciplinary theoretical approach to develop the PSS ecosystem characteristics is suggested. By challenging the presented set of characteristics and developing a set of sub variations of each: 1) use the characteristic to retro-sportively analyse best-practice PSS cases, 2) use a different research method to develop the characteristics with an aim to involve industry practitioner in the development.
- *Methodological reference model;* The PSS Conceptualisation framework should be continued as a methodological reference from where new PSS tools and methods can be developed.

Based on the research findings from this project and the research experience and insight, it is suggested that future research should focus on:

- *Multi-stakeholder co-development in PSS;* methods and development processes that support collaboration within the ecosystem around a PSS, to exploit competencies and create a cooperative ecosystem where goals are shared and aligned.

- *Tools for collaborative PSS development*; continue research to make strong normative PSS tools to strengthen collaborative design activities in the PSS development to foster intra- and inter-organisational collaboration.

- *Focus on PSS development strategies*; the development of a set of PSS development strategies, where methods are clustered to suit the different service strategies; research is ready to be transformed into a set of normative methods that industry practitioners can leverage on.

- *PSS thinking & Mental mindset*; dissemination of future research findings and implementation of new PSS methods and tools by integration and a focus on state-of-the-art communication and representation techniques to strengthen the mental mind-sets of the PSS developer.

- *Selection and evaluation of potential partnerships;* a focus on frameworks in PSS that can support the development process in the PSS ecosystem dimension, with focus on selection, evaluation, and implementation of new relationships and value structures in the ecosystem.

- *Crowd-based research and dissemination of results*; an area which has not been used in this research project or broadly in the research field of PSS is the use and exploitation of the new opportunities with crowd-based approaches where data collection, data synthesis, and, in general, research findings are presented and derived by use of online interactive platforms involving simultaneous industry practitioners as well as researchers.

- *Sharing of research data-bases and research protocols* to foster a stronger collaboration between research scholars and strengthen the empirical research foundation on which to base future research.

Appendices

Appendix A: Value proposition

Terms	Definition	Authors
Value proposition	A value proposition is composed of the products and services as well as the perceived benefits they provide. The products and services are always intertwined. From a design object perspective, products, services and PSS are all seen as value propositions that aim to fulfil a need with their customers. In essence products and services are just different alternatives to how companies deliver value to their customers.	(Tan 2010)
Product/Service-System solution	A system of integrated products and service that companies develop and deliver to customers. PSS solutions may be conceptualised by considering the product life phase systems, customer activities and the actor network. A PSS solution is a system of integrated products and services that companies develop and deliver in order to fulfil a need with their customers.	(Tan 2010)
PSS concept	The PSS concept is comprised of delivery elements codified into products, service offers and contractual agreements. In the artefact system domain, the PSS can be represented as a portfolio of offers, which is the combined programme of defined product and service propositions.	(Matzen 2009) p. 148
Product-Service system	#1: A product service system is a system of products, services, networks of actors, and supporting infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business #2: The author uses the descriptions from Goedkoop et al. (1999): A Product Service system (PS system) is a marketable set of products and services capable of jointly fulfilling a user's need.	p. 4 Mont 2002 (Mont 2004)
Product-service mix	A product-service mix is the extension of the service component around the product for business activities that are traditionally product-oriented; the introduction of a new service component marketed as a product for business activities that are usually service oriented. A product-service combination has the same meaning as product-service mix	(Mont 2000) p. 40
Value proposition = PSS	#1: PSS´s consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer	(Tukker and Tischner 2006b)p. 1

	needs #2: PSS´s are a specific type of value proposition that a business (network) offers to (or co-produces with) its clients.	
Integrated product and service offering	#1: A PSS is an integrated product and service offering that delivers value in use. #2: Servitisation is now widely recognised as the innovation of a manufacturer's capabilities and processes to move from selling products, to selling integrated products-service offerings that deliver value in use.	(Baines et al. 2007) p. 3 (Baines et al. 2009b) p. 512
Product-Service system	A Product Service system (PS system) is a marketable set of products and services capable of jointly fulfilling a user's need. The PS system is provided by either a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment.	(Goedkoop et al. 1999) p. 20
Systems of products and services	Is an integrated whole of mutually dependent products and services, that focus on meeting some specific customer demands. A PSS strategy offers a customised mix of services (as a substitute for the purchase and use of products), in order to provide a specific final result (in other words, an integrated solution to meet the customer's satisfactions). The mix of services does not require the client to assume (full) responsibility for the acquisition of the product involved.	(Manzini and Vezzoli 2002) p.4,8
Product-service combinations	"Product-service combinations (or eco-services) are those intangible service components that partially or completely substitute for tangible components, resulting in a positive effect on the environment."	(Behrendt 2003)
Product-service offering	Defines a product-service offering on a spectrum from tangible products supported with a peripheral service to total services. Defines servitisation as the journey or transformation process whereby an organisation enables its product-service offerings.	(Martinez et al. 2010)
Bundle/package of products and services	Tightly coupled combination of products and services is known as servitisation Moving from the old and outdated focus on goods and services to integrated "bundles" of systems, with services in the lead role. At the final stage of a servitised business a firms offer bundles consisting of	(Vandermerwe and Rada 1988) p. 316

	customer-focused combinations of goods, services, support, self-service and knowledge, between these the borders are fuzzy and indistinct.	
High-value integrated solutions (integrated solutions)	Is a pre-integrated solution consisting of; tailor made combinations of products and services. Integrated solutions add value by creating unique benefits for each customer A solution "involves the provision of tailored combinations of products and services as high-value 'integrated solutions' that address the specific needs of large business and government customers.	(Davies 2004) p. 736 (Davies et al. 2006) p. 1
High-value solutions	"In all sorts of industries, companies that traditionally have made and sold stand-alone products are changing their strategies. They are creating high-value solutions by integrating various products and services.	Foote et al. (2001) p. 84 McKinsey Quarterly
Solutions	A recent trend in business strategy is to offer solutions to customers instead of stand-alone products. The companies following a solution strategy bundle their products together and add software and services. The offering is a: Personalised packages of service, support, education consulting.	(Galbraith 2002) p. 194 p. 5
Customer solution	A solution is a combination of products and services that create value beyond the sum of all parts..., it is the level of customisation and integration that sets solutions above products or services or bundles of product and services	(Johansson et al. 2003) p. 188
Customer solution	I define a solution as an integrated combination of products and services customised for a set of customers that allows customers to achieve better outcomes than the sum of the individual components	(Sawhney 2006) p. 360
Value packages	Value package (service and goods offering mix) Service and goods offering mix, which are often sold together in single value packages	(Corrêa et al. 2007) p. 1
Solution value proposition	Solutions are more than just bundles of products and services, they are customer offerings that are tailored to suit individual requirement, often bundled into an integrated package ready to use/apply.	(Sharma and Molloy 1999) p. 2,11
Complex services	Is the provision of a set of technical capabilities based on a complex system to a customer at a contractually defined performance level.	(Neely et al. 2011) p. 1 Adapted from McFarlane and Cuthbert, 2011
Integrated	offering a bundle of physical products, services and	(Neely et al.

solutions	information, seamlessly combined to provide more value than the parts alone, that addresses customer's needs in relation to a specific function or task in their business system	2011)
Value propositions	Value propositions are borne by objects which can be products (physical goods), services, experiences, events, persons, places, properties, organisations, information, or even ideas. These are often bundled together and offered as a whole to customers. A distinguishing is made between equipment-based vs. People based services	(Kotler 2000) p. 2
Solutions	solutions as a set of customer-supplier relational processes consisting of "customer requirements definition, customisation and integration of products and services, their deployment and post-deployment customer support, all of which are aimed at meeting customers' business needs"	(Tuli et al. 2007) p. 1
Servitisation	Longitudinal relational processes, during which a provider integrates goods, services and knowledge components into unique combinations that are aimed at meeting customers' evolving business needs.	(Cakkol 2013)
Solution	"Longitudinal relational processes, during which a solution provider integrates goods, service and knowledge components into unique combinations that solve strategically important customer specific problems, and is compensated on the basis of the customer's value-in-use".	(Storbacka 2011)

Appendix B: Case companies detailed

Emerson MTM

Emerson had at the time 127,700 employees, with 640 employees in the Marine Tank Management division. They had all their product development in Denmark with 70% production in China. Their after-sales unit had 120 employees with 16 of these in Denmark. The company's core business was to provide solutions to improve efficiency and safety of all tank-related activities on the ship. They used an acquisition strategy to be able to broadly cover Marine Tank Management systems, with covered radar tank gauging, hydraulic and electro-hydraulic valve remote control, measurement using electro-pneumatics, pressure technology, and other technologies. Emerson MTM was one of the PROTEUS companies that offered well-established package solutions with a focus on long-term performance. One of the examples of PSS thinking at Emerson MTM was their offering of remote monitoring, where they supported maintenance and operation with a carefully designed monitoring system. Their biggest motivation to participate in PROTEUS was to improve their after-sales business, to increase profit and increase after-market sales. They also expressed a need for systematic service-development.

Hempel

Ready mixed-paint, was Hempel's their entrance to become a world leader of paint to the shipping industry. Today, Hempel sells quality paint together with coating expertise, through their coating consultants, in both new-built and after-sales activities called coating project management. Hempel is a large company with 5000+ employees spread in 80 countries with 650 coating advisors, 24 factories, and 10 R&D centres. An example of PSS thinking included their focus on coating expertise. They had developed an educational centre where they offered training to become a certified coating advisor. They also offered the training to competitors. The coating advising was offered in a service-level agreement where they offered the advising in three different levels. Furthermore, Hempel collaborated with a technology firm to develop a new solution for shipowners, where they would perform a TCO analysis and forecast fuel savings after a hull repaint and thereby improve surface quality. Their motivation to participate in PROTEUS was to improve the visibility of the value from the coating advisors and to increase the profitability from the technical services.

Klinger Danmark

Klinger Danmark is part of the Klinger group with more than 30 operating companies worldwide. Klinger is a well-known manufacturer of valves and sealing product with more than 160 years of experience in supply to the maritime industry. Klinger's main product portfolio comprises fluid control products, gaskets and seals. The vast experience with maritime applications and certifications had led to a recent developed service tool called Marine Valve and Seal Selection Tool, which can be seen as an example of PSS thinking. This digital catalogue supported a quick identification of the correct valve based on application area or identification number, which supported the user to find information about a specific valve or seal, utilising user's knowledge of the application. Their business were executed from own affiliations around the globe but also ship chandlers as their product to some extend can be seen a commodity shelve product. One of the company's greatest strengths is its technical knowledge about configuration and adjustment of valve or seal to a given application.

Lloyd's Register ODS

Lloyd's Register ODS specialises in engineering dynamics. The company provides expert advice to the marine, energy, and rail industries – reducing technical and commercial risk and enhancing asset performance. The company's expertise covers noise & vibration control, the dynamics of rotating machinery and the dynamics of structures. As a consultancy, Lloyd's Register ODS is a purely service-based corporation. Its maritime service portfolio includes noise & vibration assessment, sea trial assistance, measurement surveys, troubleshooting. Lloyd's Register ODS employs some 60 engineers, situated in the main office in Denmark and in satellite offices in Norway. Lloyd's Register Group as a whole includes some 7.500 people in 240 offices worldwide. Lloyd's Register ODS has earned an international reputation for highly focused R&D, which brings customers in the maritime segment to include; shipowners, shipyards, naval architects and component suppliers, worldwide. With access to the technical expertise, they can take care of a wide range of technical problems. The best example of PSS thinking is their technical consultancy services, the training helps their client to form better understanding of the problems that may occur and hopefully to a more informed choice of service.

NoreqActa

Since 1955, NoreqActa has developed and manufactured marine cranes in Denmark. The company name was until 2010, when it was acquired by the Norwegian Noreq Group. The company has expertise in building and supplying windlass (i.e. apparatus for lifting heavy weights), life rafts, MOB davits and other deck-related products. Since 2005 NoreqActa has expanded its business to include dedicated service activities on its products as a direct result of legislative requirements, stating that inspections on cranes for life-saving equipment should be carried out by certified producers. NoreqActa's produced on-deck cranes have a capacity ranging up to 50 tonnes. In addition to own and partner-based technical service activities on equipment, offerings also include performance- and service-logs through a so-called software-based "Management System". This offering is an online database which allows shipowners, other customers, partners and NoreqActa's own service staff to view and document service activities, enabling on-site tracing of past activities on each crane equipment installation. NoreqActa is represented by 35 local agents across the world, with around-the-clock service. NoreqActa has entered into collaboration with a company which produces similar products, but in a different range and without overlapping to NoreqActa's products. Both companies educate their service technicians in each other's' products, to enable both companies' technicians to service one another's equipment and thereby expand the companies' service network to the customers.

Novenco Fire Fighting

Novenco Fire Fighting (NFF) has delivered high quality fire-fighting systems for more than 60 years. Its main market is the maritime and offshore industry. NFF develops, produces, installs and commissions fire-fighting systems. The company is a world leader within water mist technology. Product development is focused on the NFF trademarked nozzle, whereas the remaining parts of the system are purchased from sub-suppliers. NFF defines itself as system developer and supplier, not as product supplier. The trademarked nozzle is only one element of NFF's business; the company's main expertise is in the configuration and dimensioning of the fire-fighting system. NFF's primary product is the XFlow System, a low pressure water mist system used for local protection, full protection and accommodation areas NFF's service offers are contracted with the customer and the company focuses on offering on-demand support for ordering spare parts or receiving product guidance. NFF also offers annual service on its fire-fighting systems as well as inspection, repairs and crew training, offered when requested by a customer. NFF's headquarters, storage and production are located in Denmark with approximately 35 employees. As a fire fighting systems supplier NFF falls within the category of safety equipment supplier. NFF has explored opportunities for collaborating with supplementary safety equipment suppliers to offer a safety package solution for its customers. Additionally, NFF has recently expanded its portfolio to include alternative fire-fighting solutions, in order to be able to offer package solutions for customers. As a safety equipment supplier, a part of securing future PSS opportunities has been to actively participate in the discussion on regulations for servicing the fire-fighting equipment at IMO. In this way NFF is able to assess and plan for future needs and opportunities for product and service solutions.

PresVac

PresVac Engineering was established around 60 years ago and is currently one of the market leaders in high-velocity pressure/vacuum valves and venting systems. The company's main area of expertise is within venting systems, such as critical safety systems. Its primary customers are shipowners and PresVac's main application area is on tankers transporting Volatile organic compounds (VOCs). On these ships, valves and venting systems are required by IMO regulations. PresVac Marine Nitrogen Systems provide the on-board capability for generating a safe storage environment for hazardous cargo, preserving perishable goods, and ensuring the safety of crew. At the same time these systems also provide significant operational cost-savings through total self-sufficiency and up to 30% energy saving over conventional systems. PresVac Engineering offers training courses for the operators of its systems and partnering service engineers. The company's strong position is reinforced through its close collaboration with IMO, as many regulations exist in connection to safety on tankers, and PresVac's expertise contributes to set the standards.

YIT (Caverion)

YIT Marine (which later shanged name to Caverion) is provider of large integrated electrical systems through electro-technical and monitoring solutions for the maritime industry. YIT Marine is a department established in 1982 within YIT A/S - the Danish part of the YIT Group, which is a large Finnish company with more than 100 years of history and currently 25,000 employees in 14 countries After the closure of Danish OSS shipyard in Lindø, YIT Marine flipped its business towards after-sales with the shipowners as its main customer. The company is taking advantages of its previous close relationship with shipyards, offering highly skilled consultancy and wide range of retrofit solutions. The knowledge gained during these years allows the company to provide consultancy support to shipowners with respect to the building of technical specifications, acting as the connector and facilitator between shipowners' and shipyards' technical discussions, and hereby expanding its service offerings holistically.

Appendix C: Table with typology for PSS offerings

Name & icon	Description of each offering
PRODUCT USE SERVICES	
 Product Offered	These can be commodities, standard and customised products or integrated systems of products sold to the customer. The products are primarily sold in new sales to the shipyard, or as after-sales offerings to the shipowner. After-sales products cover a wide range of offerings, such as retrofit products and solutions, upgrades, product packages (whole systems), spare parts, service kits etc.
 Monitoring Equipment	Devices monitor the condition of a product/system, on-unit, on-site or remotely, collecting data real-time or periodically. Such equipment enables both customer and/or the supplier to carry out preventive maintenance, reducing the risk of breakdowns. It also offers to the customer the possibility to improve the performance, efficiency and effectiveness of the product/system. Monitoring conditions of products/systems also provides the supplier with data to improve (time/quality) of repair activities, and valuable when planning the overall technical services offered to the customer, furthermore it also provides useful feedback for product/system redesign.
PRODUCT USE SERVICES	
 Condition-Based Maintenance	Maintenance based on the condition of a given product/system. Condition-based maintenance (CBM) is used to schedule maintenance services for the product/system by tracking changes in a key set of indicators that can reveal a decline in system performance or an imminent system failure. This is achieved by real-time condition monitoring or by periodic measurements, called predictive maintenance (PdM). Both real-time and periodic monitoring requires monitoring equipment to be installed. The two types of monitored maintenance differ from the time- or count-based maintenance, as the former are based on data available of the product/system at hand and the latter is a general prediction. This data can be used by customer /supplier to conduct preventive maintenance.
 Time/ Count-Based Maintenance	Maintenance based on a forecast of the requirement for maintenance of a product/system estimated by time or count-based systems. The prediction statistically determines when and what kind of maintenance is needed. A suggested schedule of maintenance is provided to the customer in the product/system manual. This offering helps the customer to have more control over scheduled inspections. After-sales agreements can be created based on this data. Suppliers can use the data in a proactive approach for contacting existing customers or new customers (as

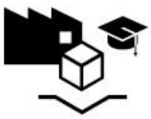
	some data can be found on databases as e.g. Fairplay), increasing after-sales [16]
 Repair	Corrective improvement of a product/system by bringing it to its original functioning state. Repair services can be provided to customers i) through unscheduled activity after a breakdown, known as corrective maintenance, or ii) as a prolongation of a preventive maintenance activity. The latter offers the customer the possibility to avoid breakdown times, eliminating subsequent loses of productivity and offering a more steadily planned flow of maintenance activities.
 Trouble-shooting	Trouble shooting is an activity, performed by conducting a systematic search for the source of a given problem. This service is offered to a customer when the symptoms of a problem can have many possible causes. It is generally of high value for the customer to identify the source of the problem as quickly as possible. Troubleshooting services are particularly useful when monitoring systems have detected an unusual condition of the system but are unable to identify the cause. Troubleshooting can be conducted remotely and on-site. The activity provides valuable information as input to corrective maintenance services. And provide the suppliers with flexibility and preparation for a possible follow up service activity (match of equipment, spares and technician). An important part of a troubleshooting service is to confirm that implemented solutions (repair etc.) have restored the product or process to its original functioning state.
 Reconditioning	Activity carried out to bring back a product/system to its original, close to original or even enhanced level of performance. Reconditioning can be achieved by readjusting and recalibrating the product/system, or through the repair of malfunctioning parts. Reconditioning is often carried out on critical components of a system. This activity can be carried out as a standalone activity, or in connection with an overhaul, inspection or a repair. It can be offered to be conducted only on certain parts of a system offered by a supplier. Reconditioning can require special equipment which is why often demounting the product/system is necessary, and brings in the possibility for the supplier to offer exchange products.

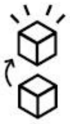
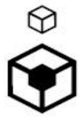
[16] Enabling maritime professionals to track live ship positions, identify merchant and military ships, contact shipowners, operators and managers, plan a port call with ease and receive insights for profitable, efficient, safe and compliant shipping.

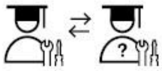
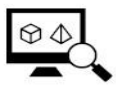
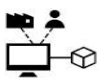
 Service Kits	Package of spare parts for a specific product/system as extra parts (critical parts) or for a specific repair task. The customer has the advantage to choose between 'standard' (can be required by regulations), 'recommended' (based on the experience of the supplier) and 'additional' spares/parts from suppliers and sub-suppliers' products (selling external parts). This offering will prepare the customer for both unscheduled and scheduled maintenance. Acting as a safety stock on board or at customer stock facilities at convenient places. Customers can use these across a fleet.
 Spare Parts On Demand	Delivery of spare parts inquired by the customer, to replace malfunctioning parts of a given product/system. The spare part on demand can be in or outside a service agreement. The spare part programme offered by the supplier can include, unique selling points as a certain availability (time/price/location) and performance (quality "e.g. ISO 9001 certified" /OEM parts). In some cases the supplier can act as a provider of other OEM spares, centralising and simplifying the process for customers. This type of agreement is the most common within spare parts services.
 Spare Part Pitstop	Extra set of spare parts, usually of a larger product/system requiring complex repair processes, packaged into a protected box (pit) which the customer can place on board or at a stock facility. The pitstop allows the customer to minimise downtime by reducing the time taken for repairs, and completely eliminating delivery time for spares. For the supplier this represents an attractive way to increase revenue from sales of spare parts whilst also reducing the need for large inventories of stock.
 Spare Parts Owned by Company	Variant of spare part service, where the customer can exchange their used or worn-out product/component, for a new or reconditioned part that the supplier has in stock. The exchanged part will have the same quality, warranty and performance as the previously installed and can be offered at a reduced price. The supplier has the flexibility of swapping spare parts between the different customers. The latter mentioned is a sharing system between the customers facilitated by the supplier.
 Spare Parts Owned by Customer	Variant of spare part service, where the customer owns a set of spare parts that the either the supplier or customer has in stock-facility. In this exchange the swapping will stay within the customers fleet, "spare part stock" the customer is sure of the availability of the spare parts, and allows the customer to have a quality guarantee of the new or reconditioned products/components used.

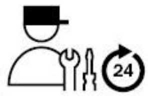
Product Manuals	Guide containing information on product installation, operation, repair, etc., which may be provided in a digital or hard copy format. Manuals can help to reduce the demand on call-centres or online digital services by providing basic information to address common questions and issues. Updates can be made to manuals, which will in the hard copy format be send by mail "a service letter", or an upgrade in the digital format (together with a notification)
Digital Product Manuals	Digitalised versions of product manuals, easing the customer's navigation through the information provided in them. These can be online or in other intermediary formats (e.g. CD-ROM, USB). Digital manuals can be offered in a standardised product manual format (e.g. Shipdex Protocol [17]), which can be directly implemented in the customers' computerised maintenance management systems (CMMS) and software application systems as Enterprise Resource Planning (ERP).
Technical Documentation	Documentation that provides technical information about a product/system. This documentation can contain information such as performance range, required service intervals, technical drawings and so on. The technical documentation is different from product manuals as they do not contain any information on operating or maintenance procedures.
Certificates	Documents attesting official recognition of products or services offered by the supplier to a customer. Certificates can support customers to ease the identification process of whether or not the ship is in compliance with a given regulation. Certificates are usually offered along with the product, service and/or system.
Warranty	Written guarantee offered by the supplier, providing assurance to the customer that specific conditions and agreements are followed throughout the offering life cycle for a certain period of time. A warranty covers the customer against malfunctions or certain causes of breakdown of the product/system. By law warranties are always included in any purchase and can vary from region to region.
Extended Warranty	Extension of the guarantee offered in a warranty, covering more malfunctions than a standard warranty and/or prolonging the period of one already offered.

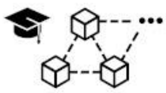
[17]Shipdex is a company offering this service to suppliers. Following the Shipdex protocol.

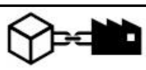
PRODUCT LIFE SERVICES	
 Delivery	Supplier service to transport a product/system or spare parts to the location specified by the customer, often within an agreed time period. This service is crucial for customer as the, distribution time is critically for many maintenance or service activities, which is why the spare part services come in many variations.
 Installation of Products	An installation service, consists of part identification (can also be done by the customer) and hereafter connecting a product/system on-board the ship ready for use. The technician can bring parts or use the parts from “stock” of the customer. Due to the system this can be more of less simple involving different degrees of assembly and disassembly. Installation by a qualified technician ensures optimal performance for the customer (some installation might require authorised technicians). Installation can occur during the new-build process of the ship, which will be offered as part of the commissioning of the product, or as part of a maintenance activity.
 Installation Consultancy	Advisory services provided during the installation process. Often these services are offered when the product is a highly integrated part of the customer system. Such services can be of benefit to the customer, when configuration of the product/system for the particular application is required to ensure optimal performance.
 Installation of Other Companies' Products	Locating and connecting a product/system provided by another company on-board the ship ready for use. This offering is usually provided via partnerships between companies, so resources are more effectively utilised and the customer receives a more efficient service.
 Commisioning / Sea Trial	Support provided during the initial operation of a given product/system, once installation is finished. Through this offering the customer can be sure the product/system has been installed correctly and is functioning as expected. Which is needed by the customer as the classing of the ship is done in this same activity. Commissioning and installation are offerings that complement each other. First-hand training for crew members during sea trials is often a component of this service.

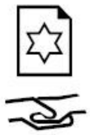
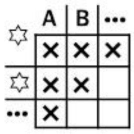
 Upgrade	Enhancement to the performance of a product/system compared to that of previous installations. Upgrades offer the customer increased productivity and can be achieved in different ways, such as: adjusting and recalibrating the existing product/system, installing newer products/systems, upgrading software or hardware, etc. Upgrade is also commonly applied to systems composed of several products, where components or products can be replaced by ones using new technologies available on the market.
 Retrofit Products	Modification of an existing product/system, adding new technology or features. Some retrofit can be motivated by the introduction of a new technology, to suit new market demands, or to meet new regulations. With this offering the customer can be sure that regardless of contracted product/system performance, if the context (technology, demand or regulations) changes, action can be taken to adapt the product/system to the new context. Retrofit activities may vary for the given change in the context, from a simple adjustment to the installation (in which case it is similar to an “upgrade”) or redesign of whole new solutions.
 Take-Back Systems	A recovery, dismantling and disposal service for an end-of-life product/system. This offering helps the customer to comply with end-of-life legislation, such as the WEEE Directive (Waste Electrical and Electronic Equipment). For the supplier, it is a source of revenue if the product/systems have been designed for profitable recycling. Take-back offerings can be an integrated element of maintenance activities, where products must be replaced and where price reductions can be accomplished on new products. Take-back systems are also a part of the exchange offering of spares, where the distribution/shipping element is vital in the offering, especially with the larger products.
CUSTOMER ACTIVITY SERVICE	
 Academy	Based on the supplier’s expert knowledge of their product/system, training courses are offered to the customer to ensure that their crew/operators have the necessary knowledge of how to operate and maintain the product/system. Courses can be offered together with product sales, in some instances this training may be required by law i.e. it is common to provide special courses on emergency situations. Courses may also be offered when upgrades have been completed on the ship in order to update the crew on the operation of the new product and ensure optimal product use and performance. These services are a way to enhance value perception of the product and to reinforce customer relationships.

 Training Other Companies' Technicians	Leveraging the supplier's existing training competencies to offer training to third party technicians. This offering usually gives the customer greater geographical coverage and more agile service activities. It may be driven by a desire from the supplier to increase the geographical scope of where they can offer technical services. Alternatively, it may be seen as useful source of additional revenue in situations where technical services are not a strategic priority for the supplier. The supplier sells directly to third party technicians and so the end-customer is not directly charged.
 Reciprocical Training	Synergistic agreement between suppliers to train and become competent in providing service activities on each other's technologies. Collaboration is achieved via a formal agreement, internally, plus a clear statement of authorisation, presented to the customer. The advantage for the customer is the reduction in transport costs and also amount of necessary contacts, to have their products serviced. This offering is seen often as part of a bigger service partnership, where suppliers also share service stations and/or workshops, thus expanding their worldwide presence.
 Digital Catalogue Identification Support	Support offered to the customer in a digital format, to identify a product based on its application area on the ship and offer direct contact to the customer or technical service. This offering is most valuable for the customer during a product breakdown, where simple and fast component identification is vital for recovery, through e.g. IMPA codes (International Marine Purchase Association). The digital catalogue helps suppliers to cut customer and technical service calls time by making sure customers have the right information about the right product.
 Management Systems	Supplier's support through IT management systems. The management system is connected to the product and/or larger systems on-board the ship via monitoring equipment. The offering can be delivered in conjunction with, for example, software for monitoring, maintenance software, etc. This service helps the customer to gain better information about the product, opening up possibilities for better performance, service, support, etc.
 Shared Management System with Customer	Supplier supports customer through enhanced knowledge and insight into the ship or fleet. The system can contain information on service history on-board the ship or across a whole fleet, including information such as service letters and performance tracking. The offering can be compared to online services. Within this offering, the information is applied via a shared software application, allowing both customers and suppliers to work on the same platform.

 Service Technicians On-Call	Remote support from technical experts on a given product/system. This can be offered as part of a call-centre or directly to individual service technicians. This offering is of vital importance for the customers in matters of urgency, or when an agile support can avoid greater problems. The service is offered by internal departments of the supplier and/or third party service technicians, depending on the suppliers' structure. In some cases customers have internal technical service centres, which first manage and prioritise arising issues and then subsequently outsource to suppliers, in order to reduce their own workloads.
 On-Site Inspections	Problem-finding activities carried out on-board the ship. To utilise the value of on-board service technicians the offering is usually complemented with repair activities. On-site inspections are a way for customers to make sure that previously undetected problems are found and repaired.
 Diagnosis plus Recommendations	Failure analysis and solution description for a given problem in a product/system. This offering provides the customer with qualified knowledge about a given issue. The diagnosis can be made based on logbooks of maintenance activities, the documentation of the products installed on the ship, condition monitoring, troubleshooting, or condition inspection of the system on-board the ship. The offering is provided separately from the actual reparation activities, which can be carried out by third parties or the same supplier. Although this can be provided as a stand-alone offering, it is mostly found as an integrated part of maintenance activities.
 Proactive Contact	Supplier's activity to continuously improve contact with, and understanding of the customer, leading to better identification and satisfaction of the customer's needs. The shift towards customer-oriented business requires high levels of product and service/system information, as well as customer needs. This is usually achieved through CRM systems, PLM systems, service reports from the ship, online ship tracking (Fairplay), etc. Proactive contact is a core activity for customer-oriented companies, which compete on anticipating their customers' needs, without appearing to be obtrusive.
 Remote Monitoring and Operation	Remote product data capture and analysis and remote product operation on behalf of the customer. This service enables the supplier to perform small product corrections ("tweaking") towards optimal performance and can be combined with preventive maintenance. It also offers valuable knowledge to the customer regarding system redesign, being able to customise product performance to specific customer needs. Knowledge about the product status and history allows for more effective

	maintenance activities and reduces downtime. To be able to offer this service, monitoring equipment needs to be set up to gather data about the product/system status.
 Planned Overhaul	This offering helps the customers to ensure that products are fully operative during important milestones, such as the five-year classification check. Furthermore Time Between Overhaul (TBO) is an indicator of the life cycle cost of the product/system, where as long as possible time between overhauls is preferred by the customer. For the supplier this offering has the advantage that it can be scheduled and planned well in advance which makes it simpler to allocate the necessary resources for the task in an efficient and cost-effective manner. TBO´s can be part of service-agreements, where price lists are included.
 Service Kits	This is a suitcase (package/kit) for the travelling technician with the necessary tools, equipment and spare parts needed for the on-site service activity. Kits can exist for several different service activities. Their use helps technicians to avoid disruptive services, caused by essential "recourses" are lacking. This helps to ensure efficient and effective service activities, regardless of who (supplier or third parties) is performing the activity.
 Design Support	Support during the planning phase for a new system development, especially when the supplier's product or knowledge is an integral part of the new system. (This can be both in new product sales and in after-sales). Design support can be offered as a direct collaboration or together with ship architects. This service prevents future problems and low performance over the life cycle of a system, resulting in a highly cost-effective offering for the customer.
BUSINESS SUPPORTING SERVICE	
 System Consultancy	Knowledge-oriented support to enhance customer business, where customers benefit from suppliers' first hand know-how on parts of their business that are not core, but still hold the capacity to increase sources of revenue. This can take the form of training in more effective competencies for ordinary routines, sharing management systems, etc. System consultancy is an advanced option to capitalise on the supplier's competencies.

 Management of Maintenance	Supplier takes responsibility for managing and delivering regular maintenance activities. Customers who sometimes do not have the competencies or time to effectively manage maintenance activities of a product will benefit from better performance from their product/systems when taking up this offering. Taking over maintenance means that the responsibility is moved from the customer to the supplier. Suppliers can take responsibility for the maintenance of several different products, including third party products, thus becoming the single point of contact, which will reduce administrative time and cost to the customer.
 Financing	Purchasing-related support for a product/system. Financial services provide alternative means for the customer to pay for their usage of the product/system. This can reduce up-front costs and free-up cash for use in other areas of the business. These services can benefit the supplier as they provide an opportunity to discuss the Total Cost of Ownership (TCO) of the product and establish a long term relationship with the customer, rather than a one-time transaction. In this scenario the supplier is able to increase its profits and its customer acceptance, via through-life services. Examples of financial services include payback programmes, leasing, pooling, pay-per-use, pay on demand, etc
 State of the Art Deals	Special price offer for a product that is being introduced for the first time onto the market. This offering represents an opportunity for the customer to get ahead of their competitors at a reduced cost. State of the art deals demand trust from the customer that the supplier has the necessary competencies and capacity to introduce the innovation to the market. The product might be offered with unique service agreements where, for example, the supplier takes greater responsibility for the performance of the product/system.
 Product Leasing for Repair Task	Provision of a replacement product/system during maintenance activities. With this offering customers benefit from reduced downtime during maintenance activities. The leased product can be stocked with the customer or where maintenance takes place, where synergies can be created with spare parts offerings, or provided by the service technicians at hand.
 Project Management	Supplier takes on the task of managing regular maintenance activities for the customer. The ultimate responsibility remains on the customer side, but the supplier is brought in to the company with the role of managing the maintenance activities. This is beneficial for products with short life cycles, where customers do not wish to focus their resources on managerial tasks. The offering can be seen as a pay-on-demand service, featuring short, flexible contracts.

 Service Agreements	Contractual agreement specifying a given service package long-term. The contract details information about the service, such as risk sharing, maintenance schedules, Time Between Overhaul (TBO), chosen technicians profile, availability of spares, prices, etc. It is common to create intermediate service agreements, where a broad range of professionals from both parties can discuss and agree the key features, leaving a more detailed version to be finalised by respective legal departments.
 Upgradeable Service Selection	A service that provides the flexibility to the customer regarding how they configure and define a service agreement, whilst also offering a simple overview of which services the supplier offers, the overview consists of all the different parameters and variants of these which contains the entire possible service package range. These can be visualised using a similar model to the approach commonly used for selecting a car wash service package, where service elements can be incrementally added on top of each other, to reach the right level of support by customising it to the exact needs of the customer. The service portfolio can also be used within the supplier's organisation to improve the sales of service agreements through e.g. the new-sales department.

Appendix D: Code for analyses

MEASURES	
Offerings	A) New or improved currently offered: - New - Improved B) Use Activity Cycle - Pre use - During use - Post Use
Servitisation	C) Service strategy continuum: - Product - Product use services - Product life services - Customer activity services - Business oriented services
Holistic	D) PSS framework: - Artefact - Service - Infrastructure - Network - Organisation
Efficacy	E) Front vs. back-office: - Front-office - Back-office F) Stakeholder type included/mentioned: - Customer - 2nd customer - Supplier - Sub-supplier - External stakeholder *(other stakeholder than supplier and sub-supplier)* - Internal stakeholder *(departments and employees)* G) Collaboration: - No collaboration - Internal collaboration - External collaboration - Customer collaboration

Feasibility	H) Long term and short term - Least feasible - . - . - . - Most feasible

Appendix E: Rules for coding

Rules for analysis		
	Front vs. Back	
#1	- Each PSS *Concept element* must be defined as front or back-office. Only one can be chosen. - Front-office is a PSS concept element that can be seen or is experienced through a change in an interaction with the customer. Back-office is everything that cannot be directly experienced by the customer. If the largest part of the PSS Concept element affect back-office, and only to a small extent front-office, it will still be categorised as front-office.	
	Front vs. Back + Service strategy continuum	
#2	- If the PSS concept element is charted as *front-office*, a *service continuum* category exists and must be charted as well. - As *front-office* PSS concept elements is everything that can be experienced by the customer it must be charted on the *Service continuum,* as the service continuum are categorizing what kind of service strategy is chosen towards the customer.	
#4	- If *front-office* is charted only one *service continuum* category can be charted. - Despite the different categories within the service continuum is fluid, one must be chosen as the strongest denominator of the PSS concept element. Many times packages are described that involves several of the service categories, still one must be selected as the most representative one.	
#3	- If the PSS concept element is charted as *back-office* - none of the *service continuum categories* can be charted - As *back-office* PSS concept elements is everything that cannot be directly experienced by the customer it cannot be charted on the *Service continuum* as all of these are different service strategies towards the customer. - A Back-office consideration can be aimed at specific *service continuum strategies,* to improve a current offering, or develop a new one; in this case the PSS concept element must be charted as front-office.	
	Front vs. Back + PSS elements	
	- For each PSS concept element – at least one element must be charted - All five elements are together describing a PSS Design. Each of these can be conceptualised, and therefore at least one of these must be represented in the PSS concept element. If none of these apply, reconsiderations must be made whether the PSS concept element is valid or not.	
#5	- If *back-office* is charted – one of the two PSS element "*network or infrastructure"* must be charted. - As a back-office PSS concept element is categorized by activities, processes, organisational structure, methods, tools, equipment etc. everything that the customer cannot perceive but is important to execute the services, or produce the product, the *network* or the *infrastructure* is the two PSS elements that	

	needs to be defined. The *organisation element* is mapped automatically together with the charting of stakeholders, by the category *internal*. Basically the differentiation is made here, with network and infrastructure to be external to the company, and the organisation to be everything internally to the company.
	PSS elements and service continuum (Front-office)
#6a	- If a *Front-office* Concept element is not charted in the PSS element "*service*" none of the service strategies (product use, product life, customer activity, business oriented - services) can be charted. - The two PSS element (artefact and service) is by detailing describing the value proposition offered to the customer. Therefore if the PSS concept element is front-office, at least one *service strategy* must be selected (#2), - and moreover if it is not charted in any of the service strategies (*product use, product life, customer activity, business oriented - services*) the PSS element "service" cannot be charted.
	- If a Front-office Concept element is charted as a PSS element "service" one of the service continuum strategies (*product use, product life, customer activity, business oriented – services)* must be charted as well.
#6b	- *If a Front-office PSS Concept element is charted as any of the five service strategies except "product" (product use, product life, customer activity, business oriented - services) the PSS element "service" must be charted as well.* - The two PSS element (artefact and service) is by detailing describing the value proposition offered to the customer. Therefore if the PSS concept element is front-office, at least one *service strategy* must be selected (#2), and moreover if a service strategy is charted the *PSS element "service"* must be charted as well.
#7	- If a *Front-office* PSS concept element is charted on the service continuum as "*product*", the PSS element "*artefact*" must be charted as well. - The opposite can be possible, as multiple PSS element can be charted – A PSS concept element can therefore be described by both PSS elements "Artefact and service", but in this case it will belong to one of the service continuum strategies (*product use, product life, customer activity, business oriented – services)* Described in (#6b) - This does not apply the other way around. If the *PSS element "Artefact"* is marked the *service continuum category* "*product*" is not necessarily the strongest denominator of the PSS concept element!
#8	- If a PSS concept element is charted as *front-office*, one of the *PSS elements "Artefact or Service*" must be charted as well. - It´s not possible that a *front-office* PSS concept element can be described only by the system PSS elements (network and infrastructure) Therefore if only these are charted and a category in on the *service continuum* is charted its false
	Stakeholder and PSS elements

#9	- If any *stakeholders* are mentioned in the PSS concept element the *PSS element "network"* must be charted as well - The network is described by stakeholders, and all the stakeholders therefore belongs to the PSS element "*network", or* the PSS element *"organisation*" (see below #10). - The *PSS network element* is divided in internal (within the organisation "intra-organisational considerations) and external (outside the organisation "inter-organisational considerations). Therefore despite if its internal or external stakeholders that are mentioned within the PSS concept element the PSS element "*network*" must be charted.	
#10	- If the stakeholder category is charted as *internal* PSS concept elements - *the organisation*" must be charted as well. (this is done automatically in the excel sheet) - Internal stakeholders (can be departments) the network PSS elements will always be charted.	
	Network vs. collaboration	
#11	- If the PSS concept element is charted as a PSS element "*network*" – one of the "*collaboration categories*" must be charted as well. - *(N = no collaboration, E = external collaboration, C = collaboration with customer, I = collaboration internally)*	
	Stakeholder vs. collaboration	
#12	- If a PSS concept element is charted within the collaboration category customer, the *Front-office* must be charted as well. - Within the stakeholder category the customer do not necessarily needs to be charted if the collaboration with customer is charted, as this can be implicit in the PSS concept element, and not detailed by the participant.	

Appendix F: Theory areas and their potential applicability to CNO modelling

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Table 4 Some theories and their potential applicability in CNOs

Theory/Tool	Potential contribution to CNO modeling
Benchmarking	[FD] Assessment of performance in comparison with a reference (benchmark), including assessment of processes, trustworthiness, and suggestion of best practices.
Complexity theories	[FD] Methods for forecasting emergent behavior, trustworthiness, etc.
	[BD] Modeling of emergent behavior in advanced networks.
	Qualitative (macro) understanding of CNO's life cycle.
Decision support	[FD] Give a basis for developing methods to assist humans in decision making.
Deontic logic	[BD] Represent in a formal way aspects such as "it is obligatory that …", "it is forbidden that …", "it is permitted that …", which can be useful in the governance of behavior.
Distributed group dynamics	[SD] Focus on inter-group relationships such as power, leadership, etc,
	[BD] Analysis of leadership behavior, hostility, compliancy, etc.
Diversity in work teams	[SD] Characterization of the diversity of individuals and cultures found in CNOs and analysis of the potential induced by this diversity.
Evolving ontologies	[CD] To capture the evolution of mutual understanding among members of the network, but still is offering limited results.
Federated systems	[SD] Providing a vision of the CNO as a federation of autonomous, heterogeneous, and distributed sources of resources (data /information, services). Relate roles with authorized access to and visibility of resources.
	[CD] Distributed data/information repositories.
Formal engineering methods	[SD] [CD] [FD] [BD] Rigorous specifications (mathematical-based) with potential application in verification and synthesis of systems. Very hard to apply.
Formal theories	[SD] [CD] [FD] [BD] Solve design problems (architecture, protocols, verification of specifications according to correctness and completeness), but very hard to develop. If developed for specific perspectives/subsystems, can contribute to reduce ambiguities and provide a sound basis for further developments.
Game theory	[FD] Can provide concepts for decision-making, e.g.: – Cooperative game theory: distribution of responsibility and resources. – Non-cooperative game theory: selection of partners, sustaining cooperation and trust building.
	[BD] Model interactions with formalized incentive structures.
Graph theory	[SD] Representation of the structure of the network —topology, routing, activity, flow.
	[FD] Methods to perform computations on flows and optimization.
Knowledge mapping	[CD] Providing visual representations of knowledge which can facilitate analysis of the CNO and its resources.
Memetics	[BD] Help understanding some aspects of the dynamics of evolutionary processes (cognitive and business) in multi-cultural contexts.
Metaphors	[SD] [CD] [FD] [BD] Quick description for human communication namely a possible help in expressing complex ill-defined concepts.
	Can be used in early stages (conceptual design) as long as they are not taken too literally.
ML/Bayesian networks	[FD] Use of probabilistic inference to update and revise belief values.
	Can support complex inference modeling including rational decision making systems, value of information and sensitivity analysis.
	Causality analysis and support a form of automated learning (parametric discovery, network discovery, and causal relationships discovery).
Multi-agent systems	[FD] [BD] Model societies of autonomous, distributed and heterogeneous entities, giving insights on how these societies can be organized and their behavior regulated through norms and institutions.
	[FD] Brokering, coalition formation and negotiation.
	[BD] Simulation of self-organizing behavior.
Multi-agent dependency theory	[FD] [SD] Representation of social interactions among agents—dependency relations, power relations.
Network analysis	[SD] [FD] Specialized graph theory-based algorithms for application in network management systems (mostly applied in telecommunication networks).
Portfolio theory	[FD] Decision making such as in VO creation (to select the optimal VO from a VBE)
Real options theory	[FD] Decision making, e.g. decision to create a VO for a business opportunity, evaluation of the minimum profitable bid in a call for tenders, etc.
Scopos theory	[FD] Understand transformation of information or knowledge from one cultural and language environment to others in such a way that the understanding and conception of the source information or knowledge would be the same for all.

The above table is presented as it is listed in the article where it is published. (Camarinha-Matos and Afsarmanesh 2007) p. 535-536

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