THESIS FOR THE DEGREE OF DOCTOR OF TECHNOLOGY

Developing Capability for Product-Service System Innovation

An Empirical Study in the Aerospace Industry

JOHANNA WALLIN

Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2013

Developing Capability for Product-Service System Innovation
An Empirical Study in the Aerospace Industry
JOHANNA WALLIN
ISBN 978-91-7385-943-1

Doktorsavhandlingar vid Chalmers tekniska högskola
Ny serie nr 3625
ISSN 0346-718X

Department of Product and Production Development
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Cover:
Illustration of the degree of change needed for PSS innovation

Chalmers Reproservice
Gothenburg, Sweden 2010

“The problem in this business isn’t to keep people from stealing your ideas; it's making them steal your ideas!”

Howard Aiken

Developing Capability for Product-Service System Innovation
An Empirical Study in the Aerospace Industry
JOHANNA WALLIN
Department of Product and Production Development
Chalmers University of Technology

Abstract

The manufacturing industry is transforming in order to meet global competition and offer greater value to customers. The companies are not only selling products, but also increasingly adding various types of industrial services (e.g. maintenance services, monitoring systems, engineering services, leasing etc). These **product-service systems (PSS)** are integrated offers that include both products and services. Such combinations are viewed as a way to increase customer value, increase profit, create closer ties with the customers and increase sustainability by taking responsibility for the product throughout its lifecycle. However, for manufacturing companies increased focus on service integration means new challenges because customer value is not only created through the physical products, but also with services, software and new business models. Thus, PSS innovation challenges organizations that have traditionally focused on product innovation. Successful transition into PSS innovation calls for development of PSS innovation capabilities such as improved ability for customer co-creation and facilitation of cross-functional innovation. The development of PSS innovation capability require a coordinated change of established practices, involves new ways of working, new collaborations and new methods, since service innovation principally differs in character from product innovation. This research has studied *how* to do this and *how* to develop the capability for PSS innovation. This research is based on longitudinal empirical studies at GKN Aerospace Engine Systems, where a four year industrial PhD project has been undertaken. Through the use of qualitative methods such as interviews, observations and workshops, empirical data has been collected from both the military business side (where the company is engine OEM) and the commercial business side (where the company develops components in partnership with the engine OEM).

The importance of collaboration between different areas and with customers is well reported in PSS literature; whereas this research provides insights on *how* to support collaboration for PSS innovation. In particular it describes how the different time perspectives related to products versus services affects the collaboration for PSS. Also described are the methodologies to use in PSS development that systematically support the creation of new PSS innovation offers. The establishment of a collaboration network and supportive methodology leads to the development of capability in the company. This research presents how PSS innovation capability develops through the establishment of routines and activities in early phases of PSS development.

KEY WORDS: Product-Service System, Innovation, Capability, Servitization, Aerospace, Product development, Case study

Thank you!

It has been a long journey from the start of this project to the end, and I have enjoyed it, although it has been far from easy. I would like to thank everyone who has been with me and supported me during these years.

First of all I would like to thank my principal supervisor Ola Isaksson for giving me lots of guidance and inspiration as well as challenges, I greatly appreciate it. I would also like to thank my assistant supervisor Vinit Parida for everything I have learned, for all the feedback and for the positive attitude. During the years I have also had the opportunity to get supervision from Andreas Larsson in the very beginning of the project, from Mattias Bergström during my licentiate, and now in the end from Hans Johannesson. Thank you for your support.

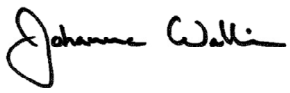
During these years of research I have had the opportunity to meet lots of other researchers, many who have become my friends. I have created a great network. A large part of it is thanks to my research school PIEp. I would like to thank everyone who I have collaborated with, discussed with, complained to and laughed with, but the list would be too long. So a large *Thank you!* to my friends and research colleagues at LTU, Chalmers, KTH, BTH, Stanford, TU Delft and GKN Aerospace Engine System. I hope to stay in touch and collaborate more in the future!

I also would like to thank all of my colleagues at GKN Aerospace Engine Systems for the support and commitment. Especially to everyone who I have interviewed and to my steering group (Ulf Högman, Patrik Johansson and Ulf Eliasson).

Funding from VINNOVA through NFFP5-6 (Nationella Flygtekniska Forskningsprogrammet) for the PLANT I-II project and from PIEp (Product Innovation Engineering program) is greatly acknowledged.

Last but not least, I would like to thank my family and friends for the never-ending support in everything I do, especially Pär, who keeps reminding me that there is more to life than research.

Göteborg, 2013



List of Appended Papers

This thesis is based on the work contained in the following papers:

Paper A

***Wallin, J.**, Larsson, A., Isaksson, O. and Larsson, T. (2011). 'Measuring Innovation Capability – Assessing Collaborative Performance in Product-Service System Innovation'. Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems, Braunschweig, Germany*

Paper B

***Wallin, J.**, Isaksson, O., Larsson, A. and Elfström, B-O. (2014). 'Bridging the Gap between University and Industry: Three Mechanisms for Innovation Efficiency'. Accepted for publication in the International Journal of Innovation and Technology Management's special issue on Exploring a designerly approach to networked innovation (to appear 2014, Vol. 11, No. 1).*

Paper C

***Wallin, J**. and Kihlander I. (2012). 'Enabling PSS development using creative workshops: Experience from industry cases'. Proceedings at the International Design Conference – DESIGN 2012, Dubrovnik, Croatia, May 21-24.*

Paper D

***Wallin, J.**, Chirumalla, K. and Thompson, A. (2013) 'Developing PSS Concepts from Traditional Product Sales Situation: The Use of Business Model Canvas'. Proceedings of the 5th CIRP International Conference on Industrial Product-Service Systems, Bochum, Germany, April 14th-15th, 2013.*

Paper E

***Wallin, J.**, Chirumalla, K. and Isaksson, O. (2013) 'Enabling organizational changes for development of product-service system offers'. Proceedings of the 19th International Conference on Engineering Design (ICED13), Seoul, South Korea, August, 2013 (Reviewers' Favorite: rated in the top 10% papers based on reviewers' scores)*

Paper F

***Wallin, J.**, Parida, V. and Isaksson, O. (2013). 'Building Product-Service System Innovation Capability in Manufacturing Industry: A Process View on Capability Development'. Revised and re-submitted to Journal.*

List of Additional Publications

***Wallin, J.**, Isaksson, O., Larsson, A. and Larsson, T. (2010). 'Measuring Innovation Capability in Technology-Focused Development', proceedings of the 17th International Product Development Management Conference, Murcia, Spain, June 13-15.*

***Wallin, J**. (2011). 'Increasing Innovation Capability of Product-Service Systems through Collaborative Networks', Licentiate Thesis, Division of Innovation and Design, Luleå University of Technology, Luleå, Sweden.*

*Nilsson, S., **Wallin, J.**, Benaim, A., Annosi, M.C., Berntsson, R., Ritzen, S. and Magnusson, M. (2012). 'Re-thinking Innovation Measurement to Manage Innovation-Related Dichotomies in Practice', proceedings of the Continuous Innovation Network Conference – CINet 2012, Rome, Italy, September 17-18.*

***Wallin, J**. (2012). 'Turning Internal Product Knowledge into External Service Offers: Building PSS Capabilities', proceedings of the 4th CIRP International Conference on Industrial Product-Service Systems, Tokyo, Japan, November 8th-9th, 2012.*

***Wallin, J**. (2013). 'The Servitization of the Aerospace Industry and the effects on product development', proceedings of the 4th CEAS Air and Space Conference, Linköping, Sweden, September 16th-19th.*

Table of Contents

1 INTRODUCTION 1

1.1 THE INDUSTRIAL CHALLENGE OF THE AEROSPACE INDUSTRY 3
1.2 RESEARCH BACKGROUND AT THE CASE COMPANY 5
1.3 RESEARCH PURPOSE 6
1.4 DELIMITATION 7
1.5 OUTLINE OF THE THESIS 8

2 THEORETICAL FRAMEWORK 9

2.1 PRODUCT-SERVICE SYSTEMS 9
2.1.1 The design and development of PSS solutions 13
2.2 INNOVATION 15
2.3 CAPABILITY DEVELOPMENT 17
2.4 ENABLERS FOR PSS INNOVATION CAPABILITY 19
2.4.1 Internal collaboration 19
2.4.2 External collaboration 20
2.4.3 Supportive methodology for PSS innovation 22

3 RESEARCH QUESTIONS 25

3.1 TOWARDS A CONCEPTUAL MODEL OF PSS INNOVATION CAPABILITY 25
3.2 DEVELOPING RESEARCH QUESTION 1 26
3.3 DEVELOPING RESEARCH QUESTION 2 27
3.4 DEVELOPING RESEARCH QUESTION 3 27

4 RESEARCH APPROACH AND METHODOLOGY 29

4.1 AN INDUSTRIAL PHD PROJECT 29
4.1.1 The case company: GKN Aerospace Engine Systems 30
4.1.2 Study your own organization 31
4.2 EMPIRICAL CASES 32
4.2.1 CASE 1: Commercial aerospace engine component development 32
4.2.2 CASE 2: Military aerospace engines – Life Tracking System (LTS) 33
4.2.3 CASE 3: Automotive – cross case 34
4.3 RESEARCH PROCESS AND DESIGN 34
4.3.1 Design Research Methodology (DRM) 34
4.4 DATA COLLECTION AND ANALYSIS 38
4.4.1 Qualitative data collection 38
4.4.2 Analysis of empirical data 39
4.5 QUALITY ASSESSMENT OF CONDUCTED RESEARCH 40
4.5.1 Construct validity 40
4.5.2 Internal validity – Trustworthiness 40
4.5.3 External validity – Generalizability and transferability 41
4.5.4 Reliability – Recoverability 42
4.5.5 Verification 42

5 SUMMARY OF APPENDED PAPERS 43

5.1 PAPER A: MEASURING INNOVATION CAPABILITY – ASSESSING COLLABORATIVE PERFORMANCE IN PRODUCT-SERVICE SYSTEM INNOVATION 44
5.2 PAPER B: BRIDGING THE GAP BETWEEN UNIVERSITY AND INDUSTRY – THREE MECHANISMS FOR INNOVATION EFFICIENCY 46
5.3 PAPER C: ENABLING PSS DEVELOPMENT USING CREATIVE WORKSHOPS – EXPERIENCE FROM INDUSTRY CASES 47
5.4 PAPER D: DEVELOPING PSS CONCEPTS FROM TRADITIONAL PRODUCT SALES SITUATION – THE USE OF BUSINESS MODEL CANVAS 49
5.5 PAPER E: ENABLING ORGANIZATIONAL CHANGES FOR DEVELOPMENT OF PRODUCT-SERVICE SYSTEM OFFERS 51
5.6 PAPER F: BUILDING PRODUCT-SERVICE SYSTEM INNOVATION CAPABILITY IN MANUFACTURING INDUSTRY: A PROCESS VIEW ON CAPABILITY DEVELOPMENT 53

6 KEY FINDINGS 55

6.1 RQ1: HOW CAN COLLABORATION ENABLE PSS INNOVATION CAPABILITY DEVELOPMENT? 55
6.2 RQ2: HOW CAN SUPPORT METHODOLOGY ENABLE COLLABORATION FOR PSS INNOVATION CAPABILITY DEVELOPMENT? 57
6.3 RQ3: HOW CAN PSS INNOVATION CAPABILITY BE DEVELOPED? 59

7 DISCUSSION AND CONCLUSION 61

7.1 THEORETICAL IMPLICATIONS 62
7.2 IMPLICATIONS FOR PRACTICE 64
7.2.1 Creating a PSS mindset 64
7.2.2 Creating a PSS innovation climate 64
7.2.3 Creating a network for PSS innovation collaboration 64
7.2.4 Creating PSS business models 65
7.2.5 The importance of strategies 65
7.2.6 Building PSS innovation capability 66
7.3 REFLECTIONS ON QUALITY ASSESSMENT OF CONDUCTED RESEARCH 66
7.3.1 Construct validity 66
7.3.2 Internal validity – Trustworthiness 66
7.3.3 External validity – Generalizability and Transferability 67
7.3.4 Reliability – Recoverability 68
7.3.5 Verification 68
7.4 SUGGESTIONS FOR FURTHER RESEARCH 68
7.5 CONCLUDING REMARKS 69

REFERENCES 71

APPENDICES

PAPER A
PAPER B
PAPER C
PAPER D
PAPER E
PAPER F

1 Introduction

This first chapter of the thesis provides an introduction to the research topic and the focus in the thesis. It introduces the concept of product-service systems (PSS) which is the core research area in which this thesis aims to contribute. The chapter starts with a wide perspective on industrial changes in the world and then narrows the scope to the aerospace industry and the research background at the case company. The chapter also presents the purpose of the research and the delimitations.

Established organizations have formalized and structured ways of functioning. However, when the world around the organization starts to change, the need to revise and improve the way of working becomes evident. Companies need to continually adapt to changes, in order to stay competitive, and innovation plays an important role in a changing environment. The manufacturing industry is currently in the middle of a transition that requires a fundamental change in established practices. Although an increasing proportion of the revenue for manufacturing companies is generated through services rather than from the products, still the change in ways of working continues to be "slow".

Globalization, new technologies and increased environmental concerns are changing human behavior and our expectations on the products we buy. In the manufacturing industry the focus has been on product development. In order to be successful effort has been put on cost reduction and efficiency. However, globalization is making it harder for the western world to be cost competitive. The market increasingly demands products that are customized, yet available with short delivery times. Consequently, the business focus is shifting from designing and selling physical products, to supplying a system of products and services that are jointly capable of fulfilling users'/customers' demands, while also reducing total life-cycle costs and environmental impacts. What creates value for the customer is not only the physical product but the experience of using it, the services and software that are connected to it and the trust of quality and availability. This means that the companies not only need to develop their products, but also services, software and business models that enhance value for customers and users. The interaction with customers can be maintained through services, and the follow up of the product through its lifecycle can provide valuable knowledge for new products and services.

In the manufacturing industry there have been several examples of this transition from focusing on the product to providing integrated combinations of products and service offers (table 1). Such integrated offers are known as product-service systems (PSS) and consists of a mix of tangible

products and intangible services designed and combined so that they jointly are capable of fulfilling customer needs (Tukker & Tischner, 2006).

Baines et al (2009) highlight three factors that drive manufacturing companies to adopt PSS; financial (for a higher profit margin or more stable income), strategic (to gain competitive advantage) and marketing (to use services to sell more product).There are also ecological and sustainable aspects related to integrated product and service offers. Since services can extend the product's life cycle (Vandermerwe & Rada, 1988), manufacturers may take responsibility of life cycle services, such as maintenance and repair, become more responsible for upgrades and material recycling (Mont, 2002) and it contributes to a more conscious product usage and increases resource productivity (Aurich et al, 2006). The development of PSS also contributes to more focus on need, demand and function which enhance the degree of freedom to find sustainable improvements. However, PSS are not inherently more sustainable than pure products (Tukker & Tischner, 2006), although environmental issues are typically part of the structural change towards PSS solutions (Mont, 2002).

Table 1: Industrial examples of PSS

PSS example	Industry	Explanation	Reference
Rolls Royce's: 'Total Care' – Power by the hour	Aerospace	Transition from 'offering service around existing product' to 'designing services and products that support it'	Harrison, 2006; Alonso-Rasgado, et al., 2004; Tuppen, 2009
IBM's: 'Service provision'	IT	Transition from a hardware manufacturing company to a global service provider and software company	Dittrich, et al., 2007
Volvo's: 'Soft products'	Automotive	Increased focus on "soft products" besides "hard" ones. Soft products meaning products and services that enhance the satisfaction of the customer beyond the core/hard product.	Remneland-Wikhamn, 2011

The transition from the traditional development of products to the complex PSS development is challenging for the manufacturing industry since the developer not only needs to design and analyze a product definition, but also interact directly with the user to receive information about user experience. Such relations with users and tools for evaluation of customer experience may not be in place. Consequently, the integration of a service component in an innovative solution, significantly changes the way of working regarding assessing and realizing the solution compared to traditional development of products.

As an illustration, the degree of change in innovation realization increases as the traditional hardware focused organization increases the service integration. Continuing on the path of product focused offers involves continuous development or incremental product innovation, compared to the more radical/disruptive innovative steps needed to transfer to PSS development (Figure 1). The larger the deviation from the traditional product-focused development (the degree of change), the larger is the need to build innovation capability for PSS (Davies, et al., 2006).

It is critical for manufacturing companies to learn how to compete in a changing world which is increasingly dominated by revenue from services. Manufacturers have a competitive advantage to "pure" service providers in that they own (or have deep knowledge and experience of) the product technology that enables the service. Using this product knowledge as foundation for the creation of innovative PSS solutions may therefore seem a natural path. Although, the transition to PSS innovation is not always straight forward, it involves challenges to the current practices of innovation; it may require another mindset and focus, and other capabilities and skills.

Building PSS innovation capability involves handling these challenges and finding possible solutions in a larger solution space as a new dimension of service is added. This creates more room for innovation. In a larger solutions space there is a greater need for collaboration between different areas of expertise, since it requires people and competencies from the service domain to be a part of the innovation process of products. These competencies are seldom interacting today in development of new solutions. Such collaboration between different competence areas can be a challenge in itself and therefore there is a need for support methodologies on both organization and team level for communication and creativity in order to realize innovation.

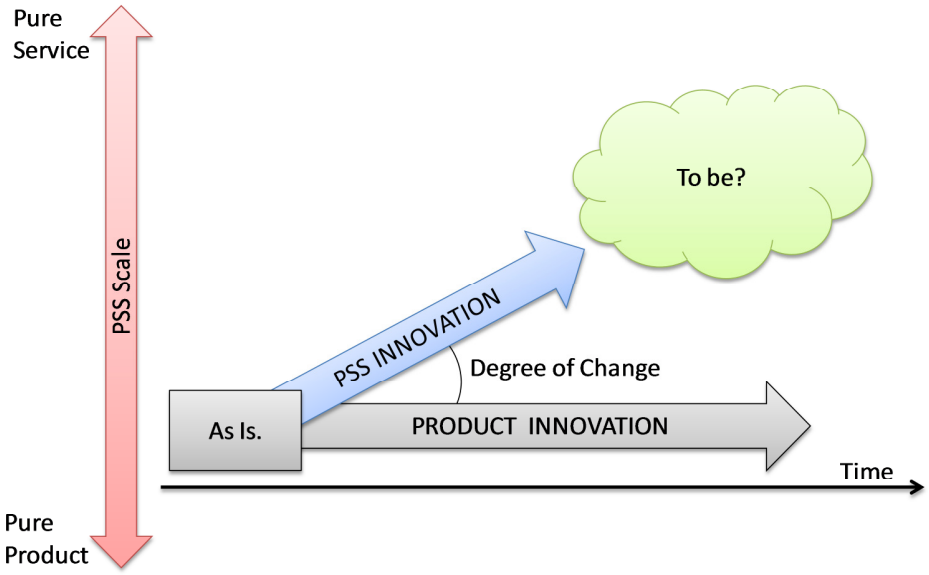


Figure 1: Degree of change needed for PSS innovation

1.1 The industrial challenge of the aerospace industry

With continued globalization, there is an increased need for fast transportation over long distances. The growth of the industry is driven by demography and economy; it is part of human nature to discover and meet others, "*if people can afford to travel, they will*" (ACARE, 2010, pp. 38). Aerospace is the industry that develops products that can overcome extreme distances quickly and at a reasonable cost. This is the reason behind the growth of the industry in the last decades. The industry is growing and will continue to grow with approximately 4-5% (growth in traffic, passenger

miles) each year in the foreseeable future (NRIA, 2013; Aerospace Growth Partnership, 2013). This means that in 15 years air travel will have doubled, which makes the environmental impact a major challenge for the industry. The era of cheap oil is over, fuel expenses and environmental concerns drive technology development and innovation in the industry. This has resulted in a 70% decrease in fuel consumption in new aircraft in the last 50 years (ACARE, 2010). Still the fuel consumption (year 2012) constitutes of 32% of the operating costs (IATA, 2013). This has lead to airlines needing to replace older aircraft with new fuel-efficient aircraft. To finance such replacement has made the industry reliant on asset-focus financiers and lending institutions that are willing to invest for the long term (ACARE, 2010).

The aerospace industry is characterized by its heavy up-front investments and long development and lifecycles of the products, which has made it expensive for the companies developing aircraft and engines (ACARE, 2010). Few companies have had the financial and technical ability to enter the complex market and SMEs (Small Medium Enterprises) are likely to struggle since they lack the ability to invest. This has lead to partnerships between companies and suppliers to share development costs and risks. As the international aerospace industry is evolving and growing, competition will be more intense in the future (Aerospace Growth Partnership, 2013).

Globalization and increased transportation has expanded the market and brought new opportunities, but as the aerospace industry is growing, new actors are emerging in the industry. When new aerospace manufacturers enter the scene further challenges arise. With increased competiveness comes the need for differentiation. (ACARE, 2010). One way of differentiation and maximizing customer value is by offering PSS offers. Trends and outlooks for the future identify PSS as the future for competition in aerospace. This implies a radical shift in terms of innovation, which challenges the organizations' capability to innovate. Thus, there is a need within the aerospace industry to gain knowledge on how to increase PSS innovation capability.

Furthermore, from a PSS research perspective, there are three main reasons why the aerospace industry is interesting for research on PSS innovation capability. First, the complexity of an aircraft engine and its long product life cycle (an aircraft engine is in use for approximately 30 years) means that each engine is an opportunity to supply a stream of spare parts and maintenance services (Ward & Graves, 2007). Second, the large expenses for the airlines when investing in a new aircraft while its revenue is only in its use (it is too expensive to have an aircraft standing on the ground), makes availability of the product and the commitment of the provider increasingly valued. This means that the introduction of PSS offers represents an important path for additional value and revenue creation for the industry. Third, there are successful PSS offers evident in the aerospace industry. One well known example in PSS literature is TotalCare® by Rolls-Royce (Harrison, 2006) or '*Power by the hour*' where airlines pay for the functionality of the engine (rather than the ownership) and receive services in a package together with the product. There are also PSS examples of services for through-life supports of the product such as monitoring systems that keep track of engine usage (Ward & Graves, 2007).

A large part of the airline's cost of the engine is related to the use-phase (with maintenance services) rather than the purchase of the engine, compared to the use and purchase of the aircraft. The demand for Maintenance, Repair and Overhaul (MRO) services is also likely to grow in the industry (Aerospace Growth Partnership, 2013).

Business models such as 'Power by the hour' have led to a steadier income for the engine Original Equipment Manufacturer (OEM) during the engine life cycle. Rolls Royce changed their business motto to be a "power provider" rather than an "engine manufacturer", and by 2008 they reported that more than 50% of their revenue actually came from the aftermarket (Tuppen, 2009). At the same time as the service and maintenance business increases in importance for the manufacturers, there is another trend that the engine life cycle is becoming shorter, primarily driven by fuel efficiency and cost of operation. Inefficient technologies need to be replaced, which keeps manufacturers focused on new product technologies. As the OEMs are increasingly becoming service providers and product technology integrators, the suppliers provide technologies, sub assemblies and solutions to integrate into the products and PSS solutions. As such, the integration of novel solutions into PSS offers can also be seen as a service itself, from the suppliers to the OEMs.

1.2 Research background at the case company

The focus for this research study has been GKN Aerospace Engine Systems, previously known as Volvo Aero when part of the Volvo Group. The company develops components and subsystems to commercial aircraft engines, and is actively developing the business as a major first tier supplier in Aerospace. Historically the company has been dominated by the military business and responsible for the aircraft engines to the Swedish Airforce. As the latest Swedish fighter was developed and introduced during the 80's and 90's there was a major focus on life cycle cost, as opposed to the acquisition cost of the actual product. The customer, the Swedish defense agency (FMV), was internationally leading in this trend. This started the need of service agreements between the customer and the provider (the manufacturer).

Service based business models were also introduced in the commercial engine business and the business model has increasingly shifted from a military domain to the commercial domain, where the company took part as a supplier and program partner in new programs. GKN Aerospace Engine System is affected by the overall servitization of the industry. The company needs to adapt to the changing revenue models of the OEMs, where much of the revenue of the OEMs comes from services and life cycle commitments after the sale of the engine.

The case company has a long history of interest in PSS, starting from the late 1990's, when the company initiated a range of research initiatives and individuals at the company took part in the invention of the concept 'Functional Products' meaning integrated systems comprising hardware and support services (Alonso-Rasgado, et al., 2004). The common theme was to understand the transition and explore how development methods, business models and quality systems were affected by the transition to service offers in the manufacturing business.

Despite the significant learnings, the transition was not as quick as anticipated. Even though the business changed, the product manufacturing basis is still dominant in many ways and the breakthrough of PSS solutions has progressed slowly. The reasons may be several, such as the fact that the aero engine business is still challenged by the performance improvements, the product design requirements are passed directly from the OEM, a majority of the employees have a traditional mechanical engineering background, and certification requirements are stringent which makes radical innovations to be thoroughly validated and verified in advance of launching into new aircrafts and engines.

The company had initiated the process of capitalizing on their internal capabilities experience in the product support domain and offer services to the commercial market. It is clear that the introduction of new business incentives was not easy to realize within the organization. Although recently, a focus on 'function' and 'value' has started to emerge at the company.

As the Volvo Group developed a strategy to adopt the service transition there was a renewed senior strategic support for what is referred to as 'Soft Products'. Even so, the transition of the new ideas seemed to take more effort to realize than what was first anticipated.

The need for a deeper understanding of what is required in the manufacturing organization, to enable innovation where the solutions constitute a mix of product and service elements, or in other words, the need to understand the underlying capabilities needed to develop PSS innovations in a similar way as "traditional" products, was the reason for the initiation of this research project. Thereby the company initiated this research project, *Planning and Innovation within Product Service Systems* (PLANT I-II) funded through VINNOVA (Swedish Agency for Innovation Systems) and the National Aviation Engineering Research Programme (Nationella Flygtekniska Forsknings Programmet, NFFP 5 and 6).

From a research perspective, this particular company is interesting to study since it has history of integrating more services to the product concepts and moved into a position as a PSS provider. It is also a company that is part of both the commercial and the military business side of aerospace, and also represents two positions on the value chain. On the commercial market, they are partners with the engine OEMs and on the military market they are the engine OEM. Hence, it can be seen as two cases within one, and represents an interesting empirical study to undertake research on PSS innovation capability.

1.3 Research purpose

Previous research on PSS has identified the servitization of the manufacturing industry, the various business models that involve both products and services, the challenges this has on the companies and the value it creates for the customer. More research is needed on how to support the companies in this transition and increase the knowledge on how to handle these challenges, how to use the product knowledge and the expertise from support of product operation to expand the offers and include services to maximize value creation. More knowledge is needed regarding how companies

can develop capability to handle these challenges and to develop improved support methodology for PSS innovation capability.

The context of this research is a manufacturing company with a strong focus on mechanical Engineering. When the solution not only contains the development of products but also services and software, it puts new challenges on the engineers and the organization that are used to the focus on products only. This research therefore takes on a design engineering approach to study how a manufacturing industry can deal with the new challenges of PSS innovation and build their capability for PSS innovation. Engineering design focuses on the development of new solutions. Hence, the purpose of this research has both a theoretical view to advance knowledge and also a practical view on supportive methodology:

The purpose of this research is to advance the knowledge about the challenges and the support methodology of developing PSS innovation capability in the aerospace industry

Previous research on PSS has focused on business-to-consumer (B2C) or business-to-business (B2B) offers, but little research has been made from the perspective of an organization that is further up the supply chain. The case company's position as a first tier supplier or partner with the OEM is therefore a rare case in PSS research.

1.4 Delimitation

This research has taken the design engineering perspective, to see how services can be incorporated into the product development and how the knowledge of the products leads to new service opportunities. The research has therefore neither taken on the service design perspective, nor products in the service development, nor services that are initiated without product knowledge as the foundation. This research is also limited to the development and not the provision of PSS offers. The innovation cycle at the case company is approximately 10-20 years (including technology development) before the effect on the market is clear. This research is therefore limited to studying and assessing immediate effects of activities and methods.

This research is related to both engineering design and management research. This is evident since it has taken the organizational (and team) perspective and not the individual perspective when researching the area of development PSS innovation capability (management research), but also studied and tested specific methods/tools for development (engineering design research).

This research is also limited to the scope of large manufacturing companies. As I have been employed at GKN Aerospace as an industrial PhD student the contextual limitation to the industry and the company has been a natural choice. The research is therefore focused on longitudinal study of one company and is not aiming to develop a broad case base. However, through the research school PIEp I have taken part in research projects together with another PhD student, where the studies have been made also at other companies. This has enabled the opportunity to go outside this delimitation.

1.5 Outline of the thesis

Chapter 1: Introduction provides a view of the industrial background, both in general terms describes the servitization and the challenges of the aerospace industry and specifically the case company that motivates the research. This chapter also presents the purpose and delimitations of the research.

Chapter 2: Theoretical Framework presents the theoretical foundation and describes how different research areas influence the research topic. Each section has a short summary for the impatient reader.

Chapter 3: Research Questions presents the research questions that have guided the research and clarifies the concept of PSS innovation capability.

Chapter 4: Research Approach and Methodology describes the research approach, the process and the qualitative methods that have been used to answer the research questions. It also presents criteria for quality assessment of the research.

Chapter 5: Summary of Appended Papers is a summary of the papers that are appended in the thesis. It also describes how the papers are linked and the distribution of work between authors.

Chapter 6: Key Findings presents the main findings while answering the research questions.

Chapter 7: Discussion and Conclusions discusses the findings while reflecting back on the existing theory (presented in chapter 2) and reflecting on the quality of the research using the criteria presented in chapter 4. The chapter also provides implications for practice, indicates the need for future research and concludes the main findings.

2 Theoretical Framework

This chapter presents the theoretical areas that are relevant for the thesis: Product-service systems, Innovation and Capability development. It also includes enablers for PSS innovation capability. Each of these sections is ended with a short summary that identifies the gaps in current research.

The theoretical framework of this thesis is founded on product-service system literature, which describes the 'servitization' of the manufacturing industry. Research on PSS is well established in the Design Society. Specifically, how to build the capability to be innovative in the development of new PSS, is however not a well explored research field. PSS innovation capability relates not only to the literature of PSS, but it also links to innovation research, since it involves an element of creativity in the degree of change. It also links to capability development research, since organizations need to develop capabilities in order to support change and be successful over time. PSS innovation capability is therefore a multidisciplinary and involves different research fields (Figure 2). This chapter will explain these different literature streams in relation to PSS.

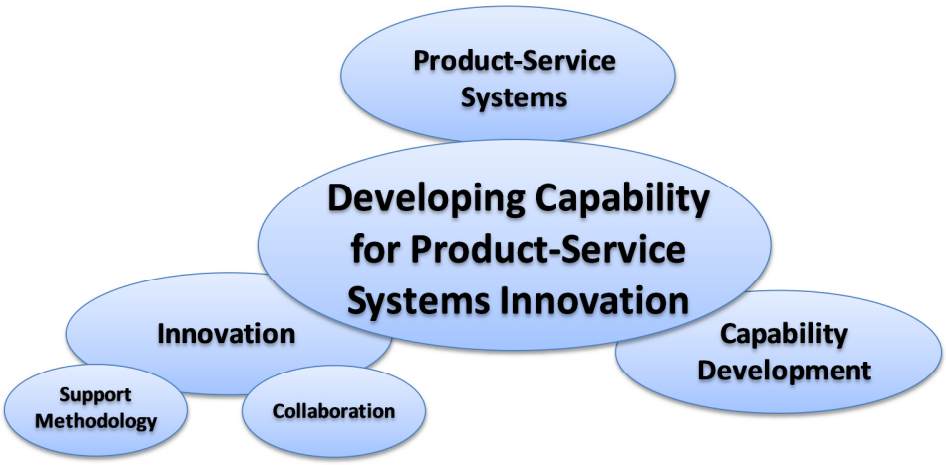


Figure 2: The different streams of literature related to the thesis

2.1 Product-service systems

In 1972 Levitt claimed that there is no service industry because everyone is in service, "*The more technologically sophisticated the generic product, the more dependent are its sales on the quality and availability of its accompanying customer services*" (Levitt, 1972, pp. 42). Levitt proposed that manufacturing industries should make customer services an integral part of their products, and that

service industries should begin to think like product manufacturers. In 1988, Vandermerwe and Rada noted the new market strategy of adding services as a way to add customer value, which leads to new customer relationships (Vandermerwe & Rada, 1988). Burger and Cann (1995) argued that companies should provide the customer with more than the traditional maintenance services to achieve customer satisfaction. In 1997, Cohen and Whang claimed that a large portion of the manufacturer's profits come from service business (Cohen & Whang, 1997). This 'servitization' is where the product-service systems literature arrives from. Mont clarified the concept of product-service systems (PSS) in 2002.

The 'servitization' has been described with many similar words (Table 2). Vargo & Lusch (2004) coined the term *service-dominant (S-D) logic*, Brady, et al. (2005) call the combination of products and services for *integrated solutions*, and Alonso-Rasgado, et al., (2004) describe *Functional Products*, Ward & Graves (2007) describe the complex combination of manufacturing and service operations as *Through-life management*. Another common nomenclatur for PSS is simply *Product Services* (Ward & Graves, 2007; Mathieu, 2001; Johnstone, et al., 2008) or Industrial Product-Service Systems (IPS2) when dealing with industrial production. In popular science it is described for example as "going down stream" when manufacturing industries need a steadier revenue (Wise & Baumgartner, 1999)or *Smart Services* in order to make the product smarter (Allmendinger & Lombreglia, 2005).

Table 2: Different terminologies of the concept of Product-Service System

Terminology	Reference	Definition
Product Service Systems (PSS)	Mont, 2002	A marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfillment or economic value.
Servitization	Vandermerwe & Rada, 1988	A market strategy of adding services as a way to add customer value, which leads to new customer relationships
S-D logic	Vargo & Lusch, 2008	Considers *service* – a process of using ones resources for the benefit of and in conjunction with another party – as the fundamental purpose of economic exchange and implies the need for a revised, service-driven framework for all marketing.
Integrated solutions	Brady, et al., 2005	Unique combinations of products and services that address a customer's specific business problems.
Functional Products	Alonso-Rasgado, et al., 2004	Integrated systems comprising hardware and support services. The Functional Product supplier provides all the support systems that are required to keep the hardware operable.
Through-life management	Ward & Graves, 2007	Through-life management involves the life-cycle management of the products, services and activities required to deliver a fully integrated capability to the customer, while reducing the cost of ownership for the customer.
Product Services (PS)	Mathieu, 2001	Service which supports the supplier's product (a typical illustration of such a service is an after-sale service), and service which supports the client's action in relation to the supplier's product (for example a training service).
Industrial Product-Service Systems (IPS^2)	Meier, et al., 2011	Are based upon product-service systems that can be defined as customer life cycle-oriented combinations of products and services to provide a higher customer value. IPS2 especially deal with dynamic interdependencies of products and services in production.

The differences arise in the motivation and geographical origin of the research communities, where PSS is a Scandinavian concept that is closely coupled with sustainability (Tukker & Tischner, 2006; Baines, et al., 2007). Further, PSS, in comparison to S-D logic and service design, has a clear connection to the product.

Baines et al. (2009) highlight three factors that drive companies to PSS; financial, strategic and marketing. There are different financial or economical arguments to transition to PSS. Services in general have higher margins than products; services provide a more stable source of revenue (Olivia & Kallenberg, 2003; Alonso-Rasgado, et al., 2004; Baines, et al., 2009; Uchihira, et al., 2008). Services can also be an opportunity to capitalize on the experience of the manufacturing (Mathieu, 2001), be used to sell more products and could contribute to higher productivity (Aurich et al, 2006). However, economical bonus with PSS is somewhat questioned by Tukker and Tischner (2006a), who say that "*Costs can be higher, if the PSS has to be produced with higher priced labour or materials, or when the often more networked production systems generate high transaction costs*."

The strategic arguments regard competitive advantages. The added services can be used to differentiate the product (Uchihira et al, 2008). Since services are more labor dependent they are also more difficult to imitate and PSS could also create new business opportunities for the company (Olivia & Kallenberg, 2003).

The marketing/customer drivers regard how services can be used to sell more products. PSS could deliver more customized solutions (Tukker and Tischner, 2006a) which are valued by the customer who demands these kinds of services when buying the product (Ward & Graves, 2007). PSS puts more focus on the use and functionality of the product; rather than the actual product itself or the ownership of the product. In some cases the use of a product (e.g. driving) can be more highly regarded than the product itself (e.g. the ownership of the car) (Uchihira et al, 2008).

Ward & Graves (2007) also point to the risk-related drivers, that could be linked to customer and/or financial drivers. Through-life services transfers risks from the customer to the supply chain.

Different kinds of services can be combined with different kinds of products in various ways, hence many different types of PSS. In literature these are often described as a continuum from pure product to pure service, with various PSS types in between (Figure 3). This shows not only the complexity within the development of a PSS offer, but also the complexity for different types of PSS. Mathieu (2001) describes two types: Service supporting the supplier's product (SSP) and services supporting the client's action in relation with the supplier's product (SSC). This focus on either the product or the user is also found in Olivia and Kallenberg's (2003) model, although they added a view on transaction or relationship based services, which has to do with the way the service is priced. Transaction-based is a price for labor and parts every time a service is provided, whereas relationship-based is a fixed price covering all services over an agreed period, where the service provider assumes the risk of equipment failure.

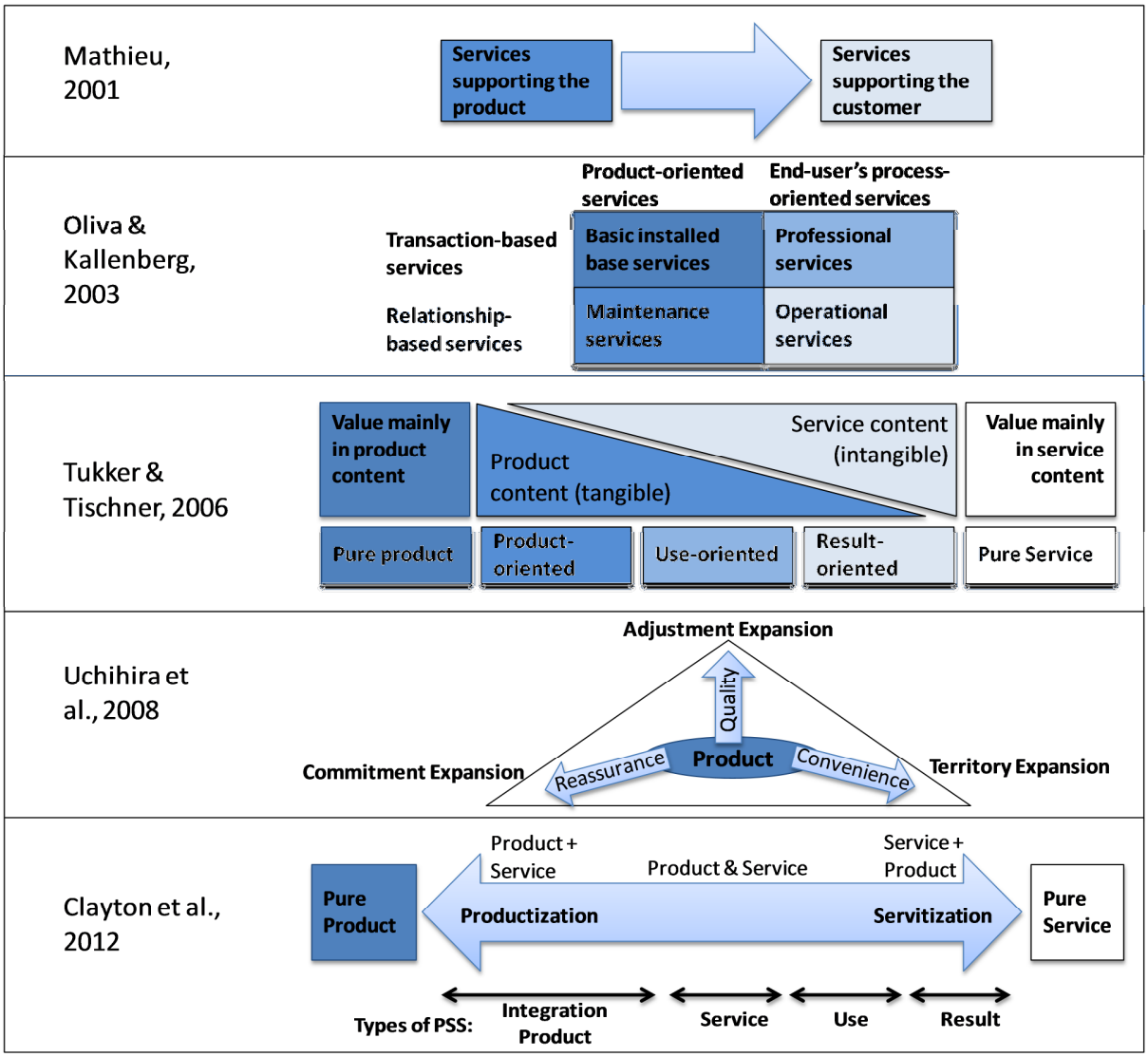


Figure 3: Different models of different types of PSS

Tukker and Tischner (2006) classifies different types of offers according to the extent of their value determined by product or service components. Product-oriented is dominated by the sales of product, although extra services are added. In use-oriented the product plays a central role, it is available for use by the customer, but it remains in the ownership of the provider. In result-oriented it is the result that is in focus and agreed upon.

Similar to Mathieu's 'services supporting the product', Oliva & Kallenberg's (2003) and Tukker & Tischner's (2006) product-oriented is Uchihira et al.'s (2008) 'Adjustment expansion' which includes services that maximise the quality of the product such as maintenance. Similar to Tukker & Tischner's 'use-oriented' is Uchihira et al.'s (2008) 'Commitment expansion' which involves the management of customer risks such as leasing or outsourcing. Uchihira et al's (2008) 'territory expansion' maximises the convenience for the customer such as one-stop solutions or service platforms. This is what

Mathieu (2001) would call 'services supporting the customer' and Oliva & Kallenberg would call it 'operational services'.

Clayton et al (2012) have a similar approach to PSS classification as Tukker & Tischner (2006) although they have divided product-oriented and added 'service-oriented' PSS which is additional value-added services that are offered as an integral part of the offering (e.g. health usage monitoring systems).

Mathieu (2001) argue that the service offer never really ends since the mission is not only to make the product work, but to maximize the different processes, actions and strategies that are associated with the product.

2.1.1 The design and development of PSS solutions

Since the context of this research is a manufacturing company with a strong focus on mechanical engineering and the research has taken an engineering design perspective, it is relevant to investigate the design and development of PSS solutions. The challenges of PSS are not only about the combination of different types of products and services, and the creation of new business models. The design and development of PSS is also challenged by the different characteristics of products and services. Reviewing the literature on PSS three main differences between products and services have been identified: First, is the time perspective. Products are first produced and then used, compared to services which are produced and used at the same time (Morelli, 2003). The lead time of product design is also longer compared to service design, and products are therefore harder to adjust to a changing environment in comparison to services (Brezet, et al., 2001). Second is the ownership. Products and services are conducted by different areas of expertise; products are conducted by product developers and technicians; whereas services are conducted by marketers, business administrators and service providers (Brezet, et al., 2001). The ownership of a product is also transferred to the customer when the product is sold; whereas the ownership of a service is not generally transferred (Morelli, 2003). Third is the design. Products have hard technical variables, such as material, dimensions etc., whereas services have soft variables, such as a time and place etc. (Brezet, et al., 2001). These differences between products and services imply barriers for the development of PSS. Brezet et al (2001) point to such barriers in regard to idea generation, since the innovation of a system is more complex and at a higher level of abstraction. Further, they point out that the transition from idea to design can be more difficult since requirement for both products and services is included, and the product and service characteristics will influence each other.

Baines, et al. (2009) found three main challenges regarding the adoption of servitization by a conventional manufacturer : the design, strategy and organisation transformation. Ward & Graves (2007) identified a number of factors that appear to impact on the transition of aerospace companies: (1) Strategic, communicating the through-life service vision, e.g. implementing a service strategy (2) Commercial, the level of business conducted, (3) Operational, maturity of lean implementation, to enhance the delivery of customer value, (4) Structural, organisational structure to support through-life management, (5) People, service and through-life management skills to

broaden the range of skills and (6) Systems, information systems to support through-life management.

The transition towards PSS involves transformations of the organization. Brady, et al. (2005) claim that companies that make the transition need to transform "*almost every aspect of the way they do business – from their business strategies and positions in the value stream, to their capabilities, organisational structures, cultures and mindset*" (Brady, et al., 2005, pp. 364). Mathieu (2001) also emphasizes the cultural change since service culture is different from the traditional manufacturing culture and also tends to be organized differently. Johnstone, et al. (2008) claimed that such cultural change needs to be in line with a clear PSS strategy.

The process of PSS development starts with a phase of need/demand identification or exploration (Isaksson, et al., 2011; Brezet, et al., 2001; Aurich, et al., 2006). Compared to product development there is a larger emphasis on this early phase to understand the customer/users needs in order to create value either by product, services or software. In PSS there is also an element of co-creation with the customer. Similar to product development this phase is followed by phases (Aurich, et al., 2006) of solution seeking and development, where ideas are generated and concepts developed. In contrast to product development, the PSS process does not end with realization. There is also a phase of solution support, evaluation or service adaptation (Isaksson, et al., 2011; Brezet, et al., 2001; Aurich, et al., 2006).

As the service integration increases the information processing and communication processes become more complex and the constraints on the cognitive capabilities of the parties grow (Mathieu, 2001). PSS methodology is an immature field and research is required to develop PSS methodologies and tools to support the development of PSS (Vasantha, et al., 2013). Vasantha et al (2013) found that PSS design is often ad hoc and lacks a systematic approach. Few PSS methodologies have been presented (more about these in section 2.4.3).

To summarize: PSS is the term used in this thesis, despite the fact that the same, or similar, concepts have been labeled differently. PSS differs from service design in the clear connection to the product. The concept of PSS is not new, it has been around since 1972, and there are several drivers for PSS (e.i. strategic, financial, marketing). PSS literature has (since 1972) described a variety of different types of PSS, from product-oriented to result-oriented. The various models that describe these types indicate that there is a need for clarification. Further PSS literature has described challenges of PSS development in general (regarding strategy, organization, culture and mindset), identified the different characteristics of products and services (which challenges the design of PSS), and identified the lack of and need for new PSS methods and tools. PSS implies changes for the development teams as well as for the whole organization and its network. Even though a lot of research has been made on the PSS phenomena, there are still gaps to be filled in the PSS literature. The transition towards PSS development is more than just a change in business models. The transition involves a change in way of working, mindset and methodology. Although PSS seems to be the future for the manufacturing industry, the adoptation to it is slow and not well reported. There is a lack in the knowledge about how to support this change/servitization, how to improve PSS innovation and how

to build innovation capability for PSS in manufacturing companies attempting the transition. In order to fill this gap, one needs to search other literature, such as literature on Innovation.

2.2 Innovation

Van de Ven (1986) stated that an innovation is a new idea or a combination of old ideas that is perceived as new to the people who are involved even though it could be an imitation of something that exists elsewhere. This view of an innovation as 'a new idea' has been argumented by several who claim that an innovation is more than a great idea, it needs to be realized, commercialized and add value for both customers and firms to be an innovation (e.g. Roberts, 1988; Hansén & Wakonen, 1997; Schramm, 2008). Crossan & Apaydin (2010) also added that innovation is "*both a process and an outcome*" (Crossan & Apaydin, 2010, pp. 1155).

Table 3: Different types of innovations

Terminology		Reference	Description
Radical	Incremental	Dewar & Dutton, 1986	Incremental innovations are improvements of existing products/services. Radical innovations create fundamental changes in human behavior
Modular	Architectural	Henderson & Clark, 1990	Architectural innovations change how components are linked. Modular innovation changes the core concept but the linkages are unchanged.
Explore	Exploit	March, 1991; O'Reilly & Tushman, 2004	Exploitation is refinement of existing technologies. Exploration is the experimentation with new alternatives.
Technology push	Market pull	Howells, 1997	Market-pull innovations are derived from a market demand. Technology push innovation derives from new technology invention.
Disruptive		Christensen, 2000	Disruptive technology is what the mainstream customers initially reject. To focus on disruptive innovation is to focus on the emerging market, where one is free to be visionary.
New to the world	New to the firm	Darroch & McNaughton, 2002	New-to-the-firm innovations are risky departures from existing business practices. New-to-the-world represent pioneering breakthroughs

Different types of innovation have also been described in innovation literature (Table 3). According to Darroch & McNaughton (2002) different types of innovation require different resources and need to be managed differently. One example of different types of innovation is incremental and radical innovation. Dewar & Dutton (1986) state that incremental innovations are improvements to existing products/services that contain a low degree of new knowledge, whereas radical innovations are revolutionary changes in technology with a high degree of new knowledge and create fundamental

changes in human behaviour or usage. Henderson & Clark (1990) also made a distinction between Architectural and Modular innovation, where Architectural innovations change the way that the components are linked together but leave the core concept and basic design of the components untouched, and Modular innovations are those where the core concept is overturned, but the linkages between the components are unchanged. Innovation can also either be derived from a market demand that is fulfilled (market pull) or from a new technology invention that is valued by the market (technology push) (Howells, 1997; Mowery & Rosenberg, 1979). However, as Mowery and Rosenberg (1979) concludes it is rather an iterative process where *both* demand and supply forces are responded to. *Another* classification of innovation is whether it addresses the existing customer or an emergent market (Christensen & Bower, 1996) or exploit/explore, where exploitation is the refinement and extension of existing technologies and the exploration is the experimentation with new alternatives (March, 1991; Benner & Tushman, 2003; O'Reilly & Tushman, 2004). Emergent markets are also discussed in literature on disruptive innovation (Christensen, 2000; Schmidt & Druehl, 2008). Disruptive innovation is what mainstream customers initially reject. To follow these customers causes, according to Christensen (2000), well-managed firms to allow strategic innovation to languish. The companies therefore need to focus on the emerging market, where they are free to be visionary in order to catch the next great wave of industry growth. The degree of novelty in innovation has also been discussed in literature in terms of 'new to the world' or 'new to the firm'. Darroch & McNaughton (2002) describes new to the world innovations as pioneering breakthroughs, and new to the firm innovations as risky departures from the firms existing business practices (which could at the same time be new to the world). Laursen & Foss (2003) introduced a three grade scale for determining this concept in innovations: (1) new to the firm, (2) new to the context/market and (3) new to the world.

The traditional view of innovation is that it takes place entirely within one company. Chesbrough (2003) referred to this as 'closed innovation' and coined the concept of 'open innovation' where the boundary between the company and its surroundings is more porous and enables innovations to move across the borders between actors. Open innovation is a wide concept, which sometimes is narrowed down to a closed network with known partners in 'networked innovation' (Valkokari, et al., 2012; Maurer & Valkenburg, 2011) (More on this in section 2.4.2: External collaboration).

According to Nahapiet and Ghoshal (1998) innovation generally occurs through combining different knowledge and experiences. A shared context between the parties, a meaningful communication and also diversity of opinions expands this knowledge. Drucker (1998) on the other hand highlights that innovation not only happens, it takes work: "*Above, all innovation is work rather than genius. It requires knowledge. It requires ingenuity. And it requires focus*" (Drucker, 1998, pp. 8).

The importance of creativity to nourish the new ideas that lead to innovation is often described in literature. Creativity is the generation of novel and useful ideas, while innovation is the process by which these ideas are captured filtered, developed and commercialized (McLean, 2005). According to Amabile (1998) creativity is a combination of expertise, motivation and creative thinking skills. Creativity is therefore supported by information sharing and collaboration. To handle these challenges and to create new innovations, companies need to develop certain capabilities.

In the aerospace industry the technology level is high; therefore there is no single technology innovation that drives future developments. ACARE (2010) rather claims that future aircrafts will be more influenced by innovations between various systems, which will lead to further widening of the collaboration network in the industry. However, innovations in the industry require large often risky investments and need to be proven in flight for safety which can hinder or delay innovations.

For PSS innovation, Ehrenfeld (2001) identified three types of changes that are significant for system innovation, 1) the change in device concept, 2) the change in infrastructure and 3) the change in user learning. Williams (2007) complemented this list with two more: 4) the change in ownership structure and 5) the change in modes of producer-user interaction. Mathieu (2001) found that the innovative ideas corresponded to services that supported the client's action rather than services that supported the product, and that consequently, managers have to enhance their firm's ability for implementing such services. Further, Joore (2008) highlights the need to clarify the various abstraction levels in PSS innovation as well as the time perspective needed for the change. This emphasizes the complexity of change and capability development for a company in the transition towards PSS innovation both internally in terms of methodologies, processes and organization, but also externally in their relationship with users and customers through the lifecycle of the PSS.

To summarize: The research on innovation goes further back in time then the research on PSS. Literature in innovation management has defined innovation, described different types of innovation, and described the means for innovation. PSS has characteristics similar to exploration, innovation that are 'new to the firm' and to disruptive innovation, since PSS involves new market opportunities, changes the traditional way of working in the organization and as disruptive innovation, PSS innovation can be an offer that the customer do not know they want. PSS innovation therefore has an opportunity to learn from the innovation domain. To understand how organizations and teams can handle the challenges of innovation, be innovative over time, create a structural change in the way of working and improve the innovation capability in the domain of PSS, it is relevant to review the domain of capability development.

2.3 Capability development

Organizational capabilities are, in general terms, what an organization is able to do (Börjesson & Elmquist, 2011). Capabilities research has its origin in the resource-based view (RBV) literature. Central in RBV is that companies can achieve competitiveness through the development of valuable and unique capabilities (Teece, et al., 1997; Helfat & Peteraf, 2003). Developing new capabilities can pave the way for organizational transitions and changes (Salvato & Rerup, 2011; Leonard-Barton, 1992).

Resources are firm specific assets that are difficult to imitate, and capability is the firm's ability to combine, coordinate and utilize these internal resources (Helfat & Peteraf, 2003; Teece, et al., 1997; Grant, 1991). According to Dosi, et al. (2000) capabilities fall between intention and outcome, the capabilities are what make the outcome bear a definite resemblance to what is the intention. Firms

with advanced capabilities are therefore through these, able to achieve competitive advantage (Day, 1994; Amit & Schoemaker, 1993).

According to Schreyögg & Kliesch-Eberl (2007) organizational capability is the result of an organizational learning process, where resources are selected, linked and developed. Routines are seen as building blocks of capabilities (Dosi, et al., 2000). These are formed through a sequence of coordinated repetitive actions (Helfat & Peteraf, 2003; Pentland, et al., 2012). Routines mature with time and reach a level of repetitive pattern which makes the firm efficient in utilizing the routines and this leads to the development of capability (Helfat & Peteraf, 2003; Teece, et al., 1997; Salvato & Rerup, 2011).

Innovation is often described in terms of changes, either changes in terms of what it offers (product/service innovation) or changes in terms of how it is created (process innovation) (Francis & Bessant, 2005). Hence, literature refers to different types of capabilities related to innovation and change, core capabilities, dynamic capabilities and innovation capabilities. Leonard-Barton (1992) describes core capabilities as the knowledge set that distinguishes and provides competitive advantage for the firm. Although the core capabilities can enable innovation since they are based on distributed sets of knowledge from multiple sources, Leonard-Barton (1992) also claims that they can at the same time hinder innovation because of the potential misalignment of them. Therefore technology-based organizations have no choice but to challenge their current paradigms according to Leonard-Barton (1992).

Dynamic capability refers to the firm's ability to adapt, renew, reconfigure, recombine and re-create their resources in line with the competitive environment (Wang & Ahmed, 2007). Dynamic capabilities facilitate the ability to recognize potential technological shifts and the ability to adapt to these changes through innovation (Rothaermel & Hess, 2007). Rothaermel & Hess (2007) further show in their research that dynamic capabilities lie across different levels, individual, firm and network, hence the firm needs to consider its intellectual human capital.

Innovation capability is the ability to manage innovation and demonstrate a successful exploitation of new ideas (Francis & Bessant, 2005). Romijn & Albaladejo (2002) highlight the ability to effectively absorb, master and improve existing technologies in order to create new ones. Further, they claim that innovation capability is built up from internal inputs (professional background, skills and efforts to improve technology) and external inputs (networks, advantages and support). Börjesson & Elmquist (2011) highlights the need for communication of ideas at all levels of the organization, to consider the whole process from idea to implementation and also the importance of insightful strategic top management. Assink (2006) found inhibitors of disruptive innovation capability, for example the inability to unlearn obsolete mental models, a risk-averse corporate climate and the lack of adequate follow-through competencies. However, Francis & Bessant (2005) claims that innovation capability is not a unitary set of attributes since different kinds of innovation may require distinctive approaches.

PSS development requires the ability to integrate with both customer/user and across product and service development departments. Internal routines that structure such integration efforts would therefore represent one building block for a distinctive capability for PSS development. Further PSS research has also discussed the importance of customer relationship management (Brady, et al., 2005; Lockett, et al., 2011) and the development of new competencies (Isaksson, et al., 2009). Brady, et al. (2005) identified four capabilities that firms need to develop as they shift towards providing integrated solutions: System integration capabilities, operational service capabilities, business consulting capabilities and financing capabilities, as well as new management skills regarding key account, risk, financial, legal, information, innovation and portfolio management.

In PSS literature there are other views on capability than the resource based view from the company perspective. Tetlay (2011) and Mo (2012) describe the capability of the system, how the PSS is capable of satisfying customer needs, where the elements in the system are the elements of the capability. Vasantha, et al. (2013) considers the capabilities of all stakeholders involved in the system, including customer/user and supply network, and argues that these capabilities are important to consider in the design of PSS and for the capability of the system.

To summarize: From the resource based view capability is what an organization is able to do, the ability to use the resources and achieve competitive advantage. Capabilities are difficult to imitate and pave the way for organizational change. Routines are building block of capability, as the routines mature over time they lead to the development of capability. Literature on capability development has described what capabilities are and different types of capabilities, some of which can be related to PSS innovation capability, but specific routines for PSS innovation capability have not been found. More research is needed related to how companies can develop such specific capabilities in practice. In PSS literature there are few studies on how to develop such PSS capabilities. In order to understand how to enable specifically PSS innovation capability, one needs to search deeper into the enablers for PSS innovation: *Collaboration* (both internal and external) and *Supportive Methodology.*

2.4 Enablers for PSS innovation capability

2.4.1 Internal collaboration

As the economy shifts from industrial manufacturing to service delivery, the terrain of innovation is expanding. As Brown (2008) notes: ”*Its objectives are no longer just physical products; they are new sorts of processes, services, IT-powered interactions, entertainments, and ways of communicating and collaborating*” (Brown, 2008, pp. 86). In today’s information society, knowledge is the new economic resource (Gill, 2002). According to Nahapiet & Ghoshal (1998) innovation generally occurs through the combination of different types of knowledge and experiences. For PSS innovation this is even more evident since it involves both knowledge of products and knowledge of services. Nonaka (1994) claims that an organization cannot create knowledge without the individuals within, it therefore needs to support the creative individuals to create the collective knowledge of the organization.

Social science has studied organizations and their networks. The social capital of an organization is built up of individuals and groups that form a network with strong and weak ties and provide information about new opportunities (Burt, 2000). In a network with strong ties everyone knows what the others know which can lead to redundant information, whereas a network with weak ties can provide heterogeneity of ideas (Granovetter, 1973).

In product development the importance of collaboration, transdisciplinarity and cross-functional teams is argued by many and seen as an essential component for innovation (e.g Holland, et al. , 2000; Brown, 2008; Björklund, 2010; Amabile, 1998). Manufacturing industries have many departments and functions, linked together in various organizational structures and each function has its sub-process. Literature often emphasizes the importance of communication (Sosa, et al., 2007), synchronization of different functions (Svengren Holm & Anderson, 2008), climate (Björklund, 2010) and to have an appropriate mix in cross-functional teams (Holland, et al., 2000). The challenge is to find appropriate practises and methodologies to support this interactive and collaborative way of working.

Annique (2007) claims that team-based job design helps to provide psychological safety, however, it also hightlights the issue of inconsistency and ambiguity for people when the reward system is individual-based.

Griffiths-Hermans & Grover (2006) emphasised the need for ties between individuals in different departments. They claim that although organizations cannot legislate ties of friendship and trust across departments, they can and should facilitate social interactions. This highlights the importance of long-term relationships for innovation.

2.4.2 External collaboration

The network of an organization is not necessarily limited to its own organization but also stretches outside. Manufacturing industries can therefore be seen as open systems. They affect the surrounding environment and are in turn influenced by it (Scott & Davis, 2007). Although an organization cannot control its environment, it can affect its relationships with surrounding stakeholders and its value proposition to customers (Håkansson & Snehota, 1989; Anderson, et al., 2006).

In the aerospace industry the interweaving of aircraft and engine and their abilities is increasing which makes collaboration between the stakeholders especially important (NRIA, 2013). There are various companies that are involved in providing air traveling: product manufacturers, maintenance companies, airlines, airports, R&D institutes, travel agencies, air traffic management, caterers etc. Some are under governmental control and others operate on the open market although still under regulations to different degrees (ACARE, 2010). The aerospace industry is characterized by large development investments; therefore many companies within the industry collaborate to distribute the costs and risks of innovation. The study by Sammarra & Biggiero's (2008) of the aerospace industry in Italy shows that the collaboration for innovation occurs through the exchange of different

types of knowledge, technological, market and managerial. Therefore, the types of capabilities that are searched through external ties also differ.

Chesbrough (2003) coined the concept of "open innovation" which changes the view that innovation is something that takes place entirely within the firm. Mathieu (2001) suggests that manufacturing companies should consider the implementation of partnerships with potential competitors, because of the level and specificity of the costs attached to the transition towards PSS. Potential partners could be the distributor, the client and the service provider. Hamel et al (1989) claim that for collaboration to succeed, each partner must contribute with something distinctive, like research, product development skills or manufacturing capacity.

Huston & Sakkab (2006) also argues the importance of the firms innovative network but emphasizes that the innovative network itself does not provide the competitive advantage: "*It's how you build and use them that matters*" (Huston & Sakkab, 2006, pp. 62-63). However, the pushing for openness conflicts with firms' need to protect their intellectual property. Henkel (2006) claims that the key is to understand what to reveal and what to protect and to find a balance between sharing and protection.

In innovation literature the relation with customers is often emphasized since an idea cannot create value without a customer and is therefore by definition not an innovation (Hansén & Wakonen, 1997; Schramm, 2008). Literature has questioned how a company can fully understand customer needs and expectations and often points to the importance of observing the user (Patnaik & Becker, 1999) or involving the customer in the innovation process (Anderson & Lindström, 2008).

Literature on PSS has also pointed out the importance of cooperation with the customer, how the transition from product development to PSS changes the relationship with the customer (Brady, et al., 2005; Lockett, et al., 2011; Mont, 2002) from a single point transaction when the customer purchases the product to an ongoing relationship through the life cycle of the PSS (Lockett, et al., 2011). PSS development implies increased contact and flow of information between provider and customer/user, which improves the relationship with the customer (Mont, 2002) and it can also maintain customer loyalty (Vandermerwe & Rada, 1988). According to Brady, et al. (2005) companies can neither respond passively to customer specification nor assume that they are set in stone but rather build long-term relationships based on trust. Therefore they need to work more closely with their customers for insights into consumers' tastes, preferences and habits (Mont, 2002). The customer orientation is necessary through the whole internal value chain (Martinez, et al., 2010).

Collaboration with other actors in the product-service chain, such as suppliers or academia, has also been emphazised in PSS literature (Mont, 2002). Cao & Zhang (2010) identified five advantages of supply chain collaboration: (1) process efficiency, (2) offering flexibility, (3) business synergy, (4) quality and (5) innovation. However, an enlarged collaboration network involves challenges when several stakeholders are involved in the design. Martinez, et al. (2010) highlights the need for a common language between provider and customer, and between different parts of the organization

for PSS and therefore suggests mobility of personnel between organizations/divisions as well as workshops involving multi-discipline personel.

2.4.3 Supportive methodology for PSS innovation

There are different views in literature on how to boost innovation in an organization. Some argue for creative freedom (Amabile, 1998) while others argue for structures (Jacoby & Rodriguez, 2007). Although one does not necessarily discount the other, there can be structures regarding certain constraints or strategic goals, but still a creative freedom regarding how to get where you want to go. Shneiderman (2007) describes three types of schools of creativity and innovation. First, the structuralist that believes people can be creative if they follow an orderly method. Second, the inspirationalist that argues that breaking away from familiar structures brings forth creative solutions. And third, the situationaliss that recognizes that creative work is social and seeks to understand the motivation of creative people.

Dougherty (2008) argues that innovation work needs to be designed so that people can come together willingly to effectively share key assets with others, even if they do not know each other. However, the team members need to have the same goals otherwise they will start pulling in different directions (McFadzean, 1999).

McFadzean (1999) divides creative methodologies in three groups. The first, paradigm-preserving techniques, which do not force the participants to venture outside their comfort zone to explore the situation. One such example is brainstorming, which is the most commonly used creative technique to solve problems (McFadzean, 1999). The second is paradigm-stretching techniques, which encourages the participants to stretch their existing paradigm and use their imagination. And the third is paradigm-breaking techniques, which brings in new elements into the situation to break perceptions and boundaries. McFadzean (1999) argues that the last two techniques produce more imaginative and original ideas. Cockayne (2013) highlight some other important aspects in the work of finding creative solutions: to understand the situation today, to seek future opportunities, and to intelligently create innovations.

Creative problem-solving methods can for example be applied in workshop format, which requires not only performance but also preparation and follow-up (McFadzean & Nelson, 1998). McFadzean & Nelson (1998) further emphasizes the importance of the competence of the facilitator to handle the dynamics in the problem-solving session. Goldenberg et al. (2003) identified five innovation patterns from their analysis of product development (which also grew from the russian methodology TRIZ): Subtraction, Multiplication, Division, Task unification and Attribute dependency change. They further claim that these patterns are not only useful to categorize new product ideas, but also for generating them.

Tools that advance creativity in individuals, and groups are important contributions in engineering innovation and different types of tools are useful for different purposes (Shneiderman, 2007). However, as Shneiderman (2007) points out although e.g. telescopes, microscopes and cameras are

powerful devices that enable innovation, "*they are still only tools; the act of creation is carried out by the users*" (Shneiderman, 2007, pp. 24).

Prototyping can be used from the early phases of innovation through to detailing and finishing of the product. Prototyping can also be used for different purposes, and different types of prototypes can be used, from simple paper mock-ups to close to the finished *product*. One advantage of using protoypes is that they can support communication of new concepts (Cockayne, 2013). Further, they help to resolve complex problems since "*good prototypes don't just communicate – they persuade*" (Kelley, 2001, pp. 39). Protoyping is mostly associated with the design of new products, but it can also be used to design service or business models.

In PSS development new methodologies have emerged that are expected to deal with the complexities that increase as service integration increases. Lee & AbuAli (2011) proposes a tool for PSS innovation that consists of a matrix that combines customers (served and not served) and needs (visible, invisible, met and unmet). Morelli (2002) points to the challenge of specifying which functions are performed by the users, and which by the service provider, which functions are automated and which rely on human action in PSS. In a later article Morelli (2006) suggests the mapping of interactions in a PSS which leads to a definition of the PSS blueprint. Tan & McAloone (2006) suggest mapping of seven PSS strategic characteristics to allow new ideas around PSS to flourish: 1) Benefit orientation, 2) Transfer of ownership, 3) Responsibility during use, 4) Management of life cycle activities, 5) Availability of offering, 6) Expansion of benefits and 7) Economic value model. Isaksson, et al. (2009) suggests that properties of maintenance conditions for assembly and disassembly be displayed directly onto the CAD model to make them instantly available and visible as a consequence of design modifications.

The transistion towards PSS development has lead to new business models for the involved companies. One quite common tool to create new business models is The Business Model Canvas proposed by Osterwalder & Pigneur (2010). It is a tool that describes and visualizes the existing business model through nine basic business elements. The advantage with the tool is that it is easy to use and the description of how to use it is easily found online. In PSS research the Business Model Canvas has been used to describe the different business model elements (e.g Barquet, et al., 2011; Kim, et al., 2012)

To summarize: Collaboration is important for both PSS and innovation in general, and PSS innovation specifically since it involves knowledge of both products and services. Different types of collaboration involved in PSS have been identified in PSS literature and suggestions have been made to increase collaboration for successful PSS. Innovation literature has also emphasized the importance of cross-functional collaboration in teams for innovation. Both PSS literature and innovation literature has pointed to the importance of collaboration with customers for value creation. The transition towards PSS also changes the customer relationship into an ongoing relationship throughout the product life cycle. In the aerospace industry collaboration between stakeholders is especially important since various companies are involved in the provision of air traveling and large development costs and risks need to be shared. Further, innovation literature has identified a lot of methods and tools for

innovation; however, there are different views on what is needed to enable innovation, i.e. creative freedom or structure. PSS literature has suggested a few methodologies and identified the need for more. The methodologies that are described have regarded PSS in general, but not considered the different types of PSS offers. There is a gap in methodologies to support companies to handle the challenges in practice involved in the transition towards PSS development, to open up the solution space and include services, to establish new relationships with customers and partners during development, to establish a through life perspective of the product and to build PSS innovation capability.

3 Research Questions

This chapter highlights the research gaps based on discussion provided in the previous chapter and presents the theoretical framework that I have used. This chapter also presents the three research questions and guides the reader to particular papers that have contributed to answering these research questions.

As stated in introduction (section 1.3), "*the purpose with this research is to advance the knowledge about the challenges and the support methodology of developing PSS innovation capability in the aerospace industry*". However, before disclosing the research questions, a clarification of what is meant with *PSS innovation capability*.

Product-service systems (PSS) are sets of products and services that jointly fulfill user's needs (Mont, 2002). *Innovation* is an idea/product/technology/service (new to the firm) that has been realized and adds value for both customers and firm (Darroch & McNaughton, 2002). Hence, *PSS innovation* is a set of products and services (new to the firm) that jointly fulfill needs and add value for both customer and firm. *Capability* is a firms ability to continuously combine, coordinate and utilize their internal resources for competitive advantage (Helfat & Peteraf, 2003; Teece, et al., 1997; Grant, 1991). Hence, for this thesis I define *PSS innovation capability* as a firms ability to utilize their internal resources to create sets of product and services that jointly fulfill needs and add value for both customer and firm.

3.1 Towards a conceptual model of PSS innovation capability

The possibility to create PSS innovations exists in all manufacturing companies, however, in order to be continuously successful in PSS offers, a systematic approach is needed where necessary capabilities need to be built and used. This thesis focuses on the development of such PSS innovation capability, which ultimately leads to PSS innovation.

Reviewing the literature there seems to be no doubt about the importance of collaboration. It is central in both innovation literature and PSS literature, hence crucial for PSS innovation capability. Innovation generally occurs through the combination of different knowledge and experiences (Nahapiet & Ghoshal, 1998) and PSS involve the knowledge of both product and service. Furthermore, PSS is often developed in co-creation together with the customer/user. Hence, it is necessary to build capability to innovate both together with customer and partners (in external collaboration) as well as in between different units within the organisaion (in internal collaboration).

In addition, there is a gap in current research regarding methods to support collaborative innovation for PSS and methodology to build capability for PSS innovation for manufacturing companies, which will lead to continuous PSS innovations on the market. These research gaps forms the base for the thesis theoretical framework (Figure 4). Thus, proposing that to holistically understand PSS innovation as an outcome, relationship between PSS collaboration, supportive methodology for PSS innovation and PSS innovation capability is important. Building on this theoretical framwork, three research questions have been developed which are motivated and presented below.

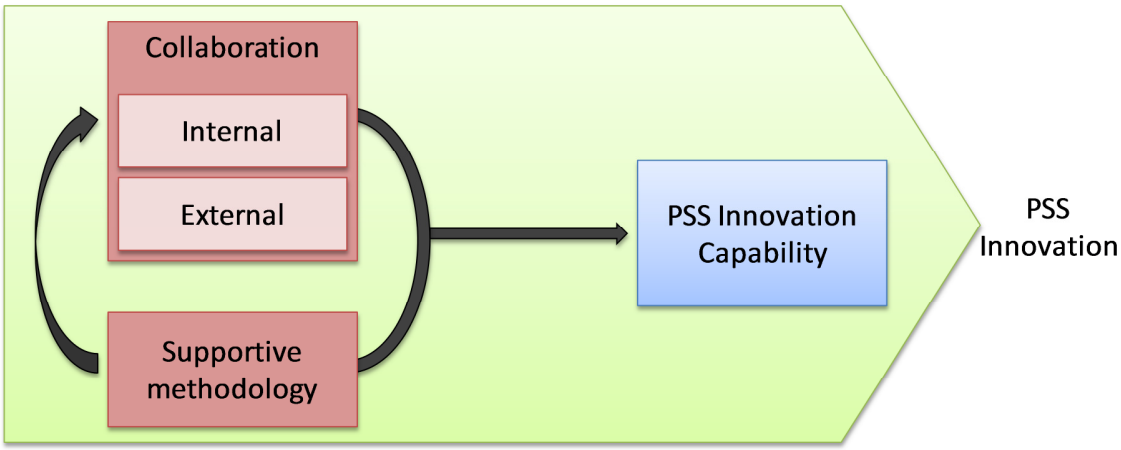


Figure 4: Theoretical Framework of PSS Innovation Capability Development

3.2 Developing research question 1

Both PSS literature and innovation literature emphasize the importance of collaboration. PSS literature suggests increased external collaboration for successful PSS, and innovation literature emphasizes the importance of cross-functional teams. For large manufacturing companies, and in the case company specifically, PSS innovation requires new sorts of relations. PSS Innovation, in contrast to product innovation, needs tighter integration and even co-creation internally (between service and product domains) and with external organizations (customer/partners). The collaborative capabilities to support PSS innovation come therefore into focus. Further research is needed to determine how these different types of collaborations overcome the challenges, leading to development of PSS innovation capability. Furthermore, research on the link between collaboration and PSS innovation capability, and how this collaboration enables the development of PSS innovation capability becomes the focus. This background leads to the first research question:

RQ1: How can collaboration enable PSS innovation capability development?

The different types of collaboration for PSS innovation capability are elaborated on in PAPER A. How to support external collaboration is described in PAPER B. How to support team collaboration for PSS innovation is described in PAPER C. The link between collaboration and PSS innovation capability is described in PAPER E and PAPER F.

3.3 Developing research question 2

PSS implies changes for the innovative teams as well as for the whole organization and its network. Innovative teams in manufacturing industries need to interact with new people and organizations effectively. Domain experts with different experiences, skills and perceptions need to understand each other, learn and build on their different skills to create PSS innovations. These complex requirements represent new challenges for collaboration and call for methodologies and tools to meet these challenges and support the collaboration. PSS literature has identified the different characteristics of products and services, and also identified the need for new methods. Literature in innovation management has tested and proposed innovation/creative methods. However, limited research has been made on what implication the new requirements have on methods and tools for PSS innovation and the build-up of PSS innovation capability. Few innovation methods have been critically tested or analyzed in PSS context, on how they meet the specific challenges of PSS innovation in practice. Therefore, the following research question is proposed:

> *RQ2: How can support methodology enable collaboration for PSS innovation capability development?*

PAPER A regards the challenge of assessing collaboration for PSS innovation capability. Methods for external collaboration are described in PAPER B. Creative methods to support team collaboration for PSS innovation are described in PAPER C. A method to create PSS Business models is described in PAPER D.

3.4 Developing research question 3

In PSS literature a variety of PSS offers have been described, from product-oriented to result-oriented. However, the research on challenges for the organization has regarded PSS in general terms, as one singe type of development. Hence there is a gap in how these different types of PSS offers affect the organization and the new methodology needed in order to build PSS innovation capability.

Capabilities literature is mainly focused on describing *what* capabilities are, but there is a need to further understand *how* companies can develop these capabilities in practice. Although a lot of research has been done on dynamic capabilities as well as innovation capabilities, which both relate to companies pursuing a change/transition and create innovative offers, this has not been applied in PSS context. Specific routines that build PSS innovation capability have not been identified and understood. PSS literature on the other hand has studied the servitization phenomenon in the manufacturing industry, but few have studied how companies can develop capabilities for this new type of development. This leads to the third research question:

> *RQ3: How can PSS innovation capability be developed?*

Organizational aspects for different types of PSS offers are addressed in PAPER E. Routines and activities to build PSS innovation capability are described in PAPER F.

4 Research Approach and Methodology

This chapter presents the research approach and methodology that has been used for the purpose of the research. I describe the pros and cons with being an industrial PhD student, the empirical cases that have been part of the research, the process that has guided the research to answering the research questions and the qualitative methods that I have used in the research. In the end of this chapter I present criteria for assessing the quality of this type of research.

The purpose with this research is to advance the knowledge about the challenges and the support methodology of developing PSS innovation capability in the aerospace industry. A qualitative approach was chosen in this research, since qualitative methods are appropriate for obtaining insights into the experiences of individuals and groups (Hartman, 2004), which in this case has been the company, the teams and individuals within. The three research questions are all 'how?' questions and qualitative research is also appropriate when answering 'how?' (or 'why?') questions. Whereas a quantitative approach would have been appropriate if the research questions were 'how often?', 'how many?' or 'when?'. A qualitative researcher can either adopt the perspective of an insider to the organization or community or an outsider, "a fly on the wall" observing the social setting as it develops independent of the researcher (Flick, 2009; Herr & Anderson, 2005). This industrial PhD project is inspired by Action research which leaves the position (as an insider or outsider) open.

4.1 An industrial PhD project

This research project was initiated by GKN Aerospace Engine System, which at the time was known as Volvo Aero Corporation. In order to enable the required in depth understanding of the conditions at the company regarding organization, culture, processes and challenges, it was conducted as an industrial PhD project. Most of my time has been spent at the company although I have at the same time belonged to a university. The first years it was Luleå University of Technology (department of Business administration, technology and social sciences, division of Innovation and design), but in the last year I transferred to Chalmers University of Technology (department of Product and production development, division of Product development).

The main part of the empirical studies has been conducted within the company. The company, which is in the aerospace industry, develops and manufactures military aircraft engines and commercial aircraft engine components in partnership with the Original Equipment Manufacturer (OEM), as well as provides services to customers and airlines. In October 2012 Volvo Aero left the Volvo Group and became part of GKN Aerospace. In this thesis I am referring to the company as GKN Aerospace

Engine Systems, although in some of the older papers the same company is referred to as Volvo Aero Corporation.

The research project (*Planning and Innovation within Product Service Systems – PLANT I-II)* has been part of National Aeronautical Research (NFFP5 and NFFP6 - Nationella Flygtekniska Forskningsprogrammet), a research program based on a cooperation agreement between VINNOVA (The Swedish Governmental Agency for Innovation Systems), the Swedish Armed Forces, the Swedish Defense Materiel Administration and industry partners such as Saab and Volvo Aero Corporation/GKN Aerospace Engine Systems. This research project has also been part of Product Innovation Engineering program (PIEp) which is a Swedish national research initiative aiming to increase innovation capability in people and organizations (www.piep.se), also financed by VINNOVA.

An industrial PhD project means that I have been employed at the case company (and am expected to continue the employment after finishing the PhD studies) and I am studying an organization that I am also a member of. An industrial PhD project is a joint project between company and university (Kihlander, et al., 2011); hence I am a member of both industry and academia, with the same academic requirements to fulfill as any other PhD student. My daily place of work has been situated inside the company but with regular visits to universities.

This research project was initiated by a company since individuals within the company had identified the issue and had a desire to change the situation. The initiation of an industrial PhD project show commitment and has enabled me to access the knowledge and data within the company. This collaborative research with a participatory nature therefore related to what is known as 'action research' or 'participatory action research' (Walter, 2009). Gummesson (2000) claims this type of research is in one way more demanding on the personality of the researcher since the researcher needs to handle both the interest of science and the interest of the client (the case company). The aim with the research is therefore both to create knowledge about PSS (scientific aim) and to support the case company in its development of PSS innovation capability. Hence, the 'actions' that have been made are related to supporting the company in this transition, with for example workshops, creating discussions or holding seminars.

4.1.1 The case company: GKN Aerospace Engine Systems

The case company develops and manufactures products to the aerospace industry. The company has two main businesses; the largest is the commercial market, where the company develops components to aircraft engines in partnership with the engine Original Equipment Manufacturer (OEM). The second market is the military, where the company develops the engines to military aircrafts, such as the Swedish Gripen fighter. In addition to these product developments, the company provides services such as maintenance and product support etc. Furthermore, the company also develops components and subsystems to European space rockets. The case company is based in Sweden with a turnover of 7 700 MSEK and approximately 3 000 employees (year 2010).

In the large commercial market the company's customer, the engine OEM receives a large part of its revenue from services and product lifecycle offers after the sale of the engine. Therefore, the case company needs to adapt to the OEMs revenue models.

The company's two business markets, the commercial and the military, put the company in two different positions in the value chain. On the military business side, the company is OEM, and on the commercial side the company is a partner to the OEM. On the military business side they have come far in service integration to the product offers and provide complete PSS offers. On the commercial side, the component development requires close collaboration with the OEM in order to handle the several interfaces each component has with other parts of the engine. This collaboration is described as a risk and revenue sharing partnership rather than a customer-supplier relationship. The company has recently increased solution offers on the commercial side as well. This transition from a product development organization with additional maintenance services to a PSS provider makes the company an ideal case in light of the research purpose.

Since the case company has been the initiator of the project, the name of the company has been revealed in some papers and also in this thesis. Regarding individuals, neither names of particular informants nor their exact title within the company have ever been revealed, only general positions such as 'project manager' so that individuals cannot be traced.

4.1.2 Study your own organization

There are inherent benefits and challenges with being an insider as an industrial PhD student. The daily position within the organization has given me close access to the industrial environment and the rich empirical data and provided important knowledge about the organization, the current situation and the culture and the challenges.

The role as a researcher demands a distant and reflective position and the challenge has been to enter the studies without preconceptions and to review the finding without bias. This has been minimized through discussions with fellow researchers and colleagues. I have used my colleagues for validation of findings. Further, plans and interview guides for example have been designed having an outsider perspective.

The closeness to empirical information has enabled intimate and continuous communication with various people across the organization and opportunities for informal discussions at coffee breaks or lunch time, which has reduced the risk of misunderstandings. Possibility to check availability in calendars has enabled booking of face-to-face meetings at short notice. Easy access to secondary data such as reports for continuous knowledge updates of the organization, knowing who knows what and understanding of industry/company specific abbreviations. This knowledge has also lead to effective interview time, since no time had to be spent on explaining the organization.

When discussing the insider perspective, my pre-knowledge of the organization prior to this research project should be presented. After writing my master thesis at the company, where I studied the concept development process, I started my employment (one year before the start of the research project) as a trainee in the company's Young Graduate Program. This position enabled a fast learning

of the organization through short internships at seven different departments, 35 interviews with various employees (board members, managers etc) and several visits to other companies and industries to study the similarities and differences compared to the own organization. The benefits with this position were that I learned a lot about the organization in a short amount of time and created a network which has been useful. I still did not *belong* to any particular part of the organization and could therefore with ease keep a distant and reflective position as a researcher.

4.2 Empirical cases

This research has mainly been focused on one single company in the aerospace industry, although the research has targeted three complementary research situations, referred to as "Cases" (Table 4). However, this company is in both the military and the commercial market and in these two markets they have different positions in the supply chain. The position in the supply change has its affects on the ability to provide PSS offers. Therefore, each business market can be viewed as a separate case. Since the commercial market is larger, both team and organizational level have been studied and since the military market is smaller in comparison and development work limited, one particular PSS team has been in focus. Further, one comparative study has also been made with a company in the automotive industry. Within each of the cases specific research studies have been undertaken and reported.

Table 4: Case descriptions

CASE	Business type	Industry	Supply chain level	Organizational level	Type of study	PAPER
CASE 1	B2B	Aerospace Commercial	Component development	Organizational and team level	Longitudinal	PAPER A, B, D,E,F
CASE 2	B2B	Aerospace Military	OEM	Team level	In-depth	PAPER C, D, E, F
CASE 3	B2C	Automotive	OEM	Team level	Cross case study	PAPER C

4.2.1 CASE 1: Commercial aerospace engine component development

Case 1 consists of a longitudinal study of the commercial market side of GKN Aerospace Engine Systems as an engine component provider to Commercial OEM's. The case therefore involves several teams. GKN Aerospace Engine Systems has grown from a *make-to-print* supplier and transferred into a *design-to-make* partner, with design responsibility for commercial aircraft engine components. The company is part of engine programs in partnership with engine OEMs such as Rolls Royce, Pratt & Whitney or General Electric. The company's partnership with these customers, on the commercial market makes the product development a service that is provided to the OEM and which delivers direct value to them as customers. It is a *Risk and Revenue Sharing Partnership* (RRSP) with the OEM, which means that contracts are signed before development starts. The company specializes in the design of certain components of the engine, and their partners have specialized in others. Dealing with the interfaces between the different components involves a lot of collaboration throughout the

development, which has made the roles of *customers* or *suppliers* blurry and the customer is rather described as "*part of the team*". The partnership with the OEM means that the projects always have an apparent customer. This creates a strong driving force for expected results, but it can also create boundaries for the innovation capability.

Developing products in the aerospace industry also implies a responsibility of this product throughout the lifecycle of its use. If an accident was to happen anywhere in the world the company is obliged to trace the activities involved with the product to make sure that other components do not have an increased risk of failure.

The company is also performing maintenance services on commercial engines. This essentially means that the company is in a competitive position with their customer/partners. The key is to provide services that are close to their own core business but in the periphery of their customer's business. A contract with the OEM is needed to carry out these types of services.

4.2.2 CASE 2: Military aerospace engines – Life Tracking System (LTS)

Case 2 involves a project initiated on the military business side of the case company called 'The Life Tracking System' project. On the military business side the case company develops the engine to the Swedish military aircraft Gripen which is used in Sweden but also in other countries. The case company also provides maintenance services and other value adding service connected to the engine and its use.

Safety is the number one priority of the aviation industry (ACARE, 2010), since there is no curb to stop at if something suddenly happens. To prevent engine failure while flying, the aircraft and engine are regularly brought in for maintenance, repair and overhaul (MRO). And the time for these MROs, or life consumption of the engine, is calculated from flight information such as number of hours in the air and number of take offs and landings.

During maintenance service of engines from different international users it was noted that the shape of the engines was different in the different countries even though it had the same amount of flight hours, take offs and landings. It was then realized that the engine was used in slightly different ways, in certain countries the pilots flew smoothly (or as smoothly as possible with a fighter), and in other countries the pilots 'played' a bit more with it, pushed the gas a bit more. This of course had its effects on the engine.

So the engineer started wondering: how can the maintenance service better be scheduled so that the user's behavior would be taken into account into the already complex calculations. In order to do such calculations there are three main challenges: First, the ability to make really fast calculations with large amount of data that includes recent flight information. Second, good relations with the users are essential in order to get hold of the flight information. Third, technical knowledge of the product is needed to understand how the use of it affects its functionality.

The idea of a possible solution emerged from the product development organization. A project at the case company was started and after years of development they were able to solve the complex task.

A software, Life Tracking System (LTS) was developed that could handle large amount of data and perform fast calculations, which made this PSS innovation reality.

The solution enabled a more accurate calculation of life consumption of the engine which could optimize the maintenance services, reduce exchange of spare parts and increase flight safety. The project stretched the established structures of product development processes and developed a product oriented service that, in 2010, received the annual technology prize at the company. It is a clear example of a PSS innovation, although focused on a service/software, it would not have been possible to provide without the access to the underlying product definition and engineering understanding and knowledge of the product.

4.2.3 CASE 3: Automotive – cross case

Case 3 is a B2C company in the automotive industry that develops cars for the global market. When buying a new car today, the buyer receives not only the hard product of a vehicle but also several offers that enhance the value of the car, such as software products, service deals, insurance packages and applications. This makes the car not only a product, but a typical example of a product-service system. The company is affected by the raised demands on services related to their products, where for instance the customers want increased connectivity. Hence the company has the need to create extended service offers to end customers through connecting the product and e.g. social media (which was the topic of the workshop arranged at the company). Since this case had similar challenges related to PSS development, but in a very different industry, it was found suitable for a cross-case study, to compare with case 2.

4.3 Research process and design

Since this research regards the development of capability for PSS innovation it has involved studies of design: the people involved in development, the process, the offers, the methods and the organization. Design has not been a topic for research as long as for example engineering sciences such as thermodynamics or mechanics material etc (Blessing & Chakrabarti, 2009). Blessing and Chakrabartis (2009) definition of design research involves both the development of understanding and the development of support. Since this is precisely the aim of this research, their Design Research Methodology (DRM) was chosen as an appropriate methodology to use. Design research is also iterations between descriptive and prescriptive.

4.3.1 Design Research Methodology (DRM)

The framework of a Design Research Methodology (DRM) (Blessing & Chakrabarti, 2009)) consists of four stages: *Research Clarification*, *Descriptive Study I*, *Prescriptive Study* and *Descriptive Study II* (figure 5) and it is an iterative design process.

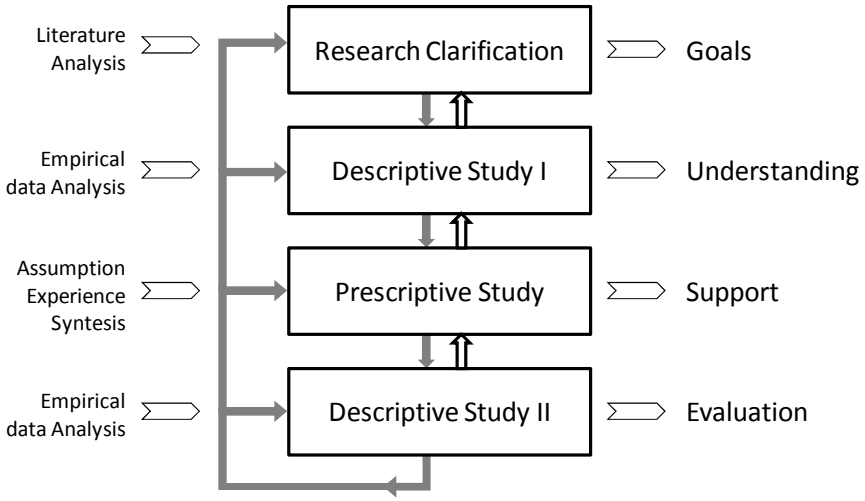


Figure 5: Design Research Methodology (Blessing and Chakrabarti, 2009)

In the first stage of *Research Clarification* the researcher defines the research goals, research problems and research questions. The *Descriptive Study I* aims to increase understanding of the existing situation through reviewing the literature, undertaking empirical research and through reasoning. In the *Prescriptive Study* the increased understanding is used to determine the key factors in order to improve the existing situation and develop intended support. The *Descriptive Study II* focuses on the evaluation of the findings from the Prescriptive Study and evaluates the support.

The process of this research is described in figure 6. The first stage of Research clarification has been a stage that has been returned to several times. Literature studies and observations at the company have been ongoing throughout the research. The beginning of the project (prior to Licentiate degree) was mainly Descriptive Study I focused on gaining an understanding of the company and its collaborative network for PSS innovation. This resulted in Paper A. This research continued with a focus on one type of collaboration network, between the company and academia. It studied the support methodologies used in this type of collaboration. This was descriptive in the beginning and turned more prescriptive to the end. The study resulted in a journal paper, Paper B. To further analyze, test and evaluate supportive methodologies for PSS innovation a Descriptive study II was performed which resulted in Paper C and Paper D. More research was needed to further understand PSS innovation within the organization, how to build PSS innovation capability and to develop the support needed. Therefore further Descriptive Study I, that towards the end turned Prescriptive, was carried out which resulted in Paper E and Paper F.

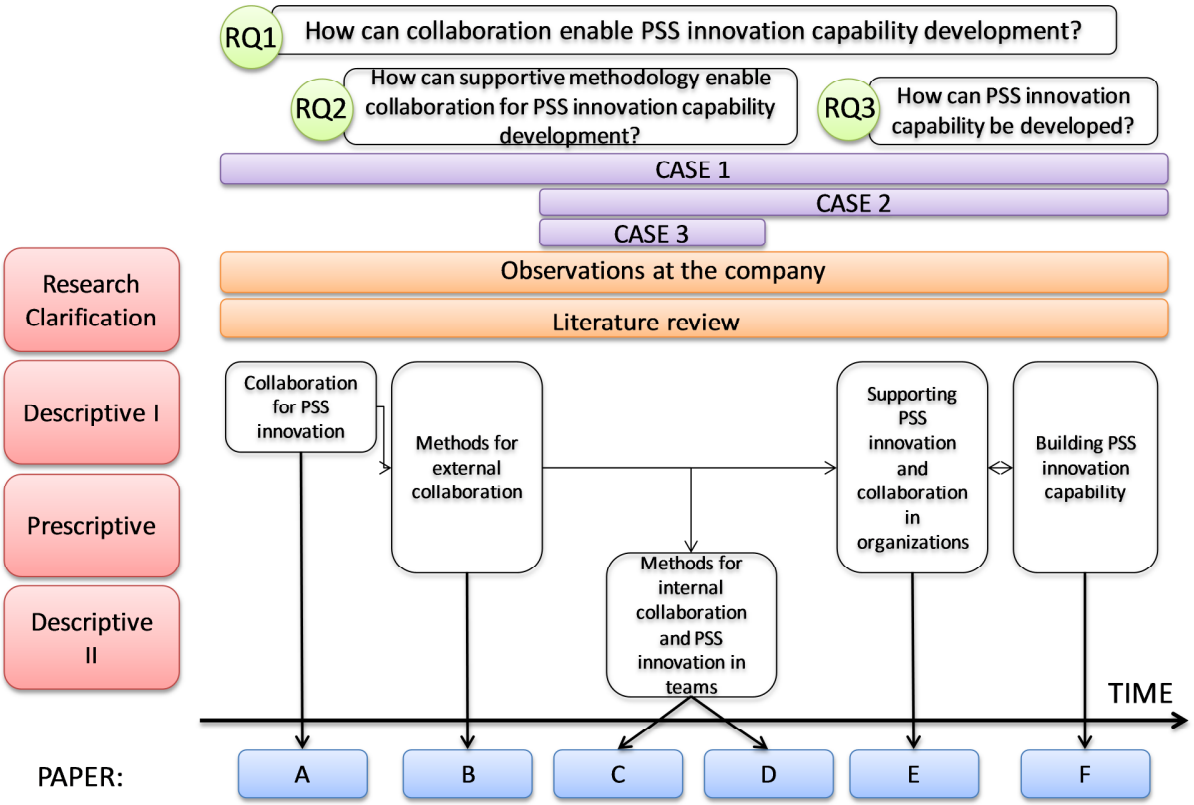


Figure 6: Research process and design

Information and data from the early studies have formed the later studies, and data has been reused when possible. All three research questions have been evident throughout the process; however in the last part research question 3 has been in focus. Each study is further described in table 5, including the purpose of each study, the guiding questions specific to the studies, how the data was collected and which appended paper was the result of the studies.

Table 5: Research studies

Study	Purpose	DRM phase	Guiding questions	Data collection	Paper
Collaboration for PSS innovation	To characterize the collaboration network for PSS innovation	DS I	How can innovation capability be increased? How can the collaboration for innovation be improved?	- Case study: project leaders/managers - Interviews of project leaders and managers (14), observations at meetings.	**Paper A**
Methods for External collaboration	To identify the mechanisms that contribute to a working collaboration between people with different contextual backgrounds	PS	How can people who are not working in the same organization get a mutual understanding? How can external collaboration be supported?	- Case study: industry/academia collaboration - Retrospective - Interviews of people with internal as well as external roles or strong external contacts (10)	**Paper B**
Methods for internal collaboration and PSS innovation in teams	To test creative workshop methods in PSS innovation teams	DS II	How can PSS development be supported by creative workshop methods?	- Case study: PSS innovation teams - Comparative study - Facilitation of workshops, incl participant evaluation (2 workshops, 17 participants)	**Paper C**
	To test how a business model tool can be used specifically to design PSS concepts	DS II	How can a business model tool support a company in developing PSS concepts?	- Case study: PSS development - Interview with Business developers (2) and interviews with PSS project members and supporters (8), observations of project meetings etc.	**Paper D**
Supporting PSS innovation and collaboration in organization	To understand the organizational changes needed for a company to transition towards PSS development	PS	What organizational changes are needed for a company pursuing different types of PSS offers?	- Longitudinal study - Interviews of managers (2) + data from previous interviews	**Paper E**
Building PSS innovation capability	To understand the process of building PSS innovation capability	PS	How can PSS innovation capability be built by routines and activities?	- Longitudinal study - Interviews of PSS-, process-, and technology developers(6), + data from previous interviews and observations	**Paper F**

4.4 Data collection and analysis

The focus has been on individuals and teams working with development of products, either in specific product development projects, service development connected to the products, technology development, business development or method/process development.

Data has been collected at different times during the duration of this research project (2009-2013). The closeness to the company as an industrial PhD student has enabled access to the industrial environment and rich empirical data which has given an in depth understanding of the conditions at the company regarding organization, culture, tools and processes. The daily placement in the company has enabled both planned and unplanned, both formal and informal interviews and observations.

The years at the company has enabled a longitudinal study of the case company, and the changes that have occurred during this time. The collaboration with personnel that have even longer experience of it has sometimes enabled a retrospective study. Collaboration with researchers at other manufacturing companies has enabled comparative studies of similarities and differences.

Literature studies have been conducted during the whole project. The insights and information from existing literature is the contextual knowledge that has been used to see the observations that have been made in this research in context. Different streams of literature have been searched with the aim to cover the areas of PSS Innovation Capability, such as for example Product-Service System, Innovation, Capability development, Reorganization etc.

4.4.1 Qualitative data collection

Interviews are particularly appropriate when one wants to study people's views, experiences, perspectives (Kvale, 2009). I have used them to understand the individual points of view of employees at the company regarding ways of working, culture, methods and processes and to understand the innovative and collaborative work at the company in general and regarding PSS specifically.

40 interviews have been performed with interviewees that have been purposive selected according to their relevance to the research topic, but also to give a representative view of the different aspects in PSS innovation. The interviewees have been from diverse sections of the organization (product development, marketing, production and engine services), from both operational and managerial levels, and were different in relation to age, experience, academic background and position, in order to capture diverse views on the innovation process and reduce bias (Eisenhardt & Graebner, 2007).

Case 1 represents several projects in the commercial business side. To get multiple inputs for how the company acts as a supplier to OEMs providing PSS solutions, several projects need to be covered. Therefore no particular project has been in focus. The interviewees represent several positions, functions and projects to capture several different views from company. In Case 2 on the other hand, that represents the military business side which is smaller and less development work is in progress, one particular PSS project has been in focus. Several people working with this particular project have

been interviewed. Since Case 1 and 2 are within the same company, and several interviewees have been involved with both market sides, these interviews could therefore regard both cases. 15 interviews have regarded Case 1 only, 7 interviews have regarded Case 2 only, and 18 interviews have regarded both Case 1 and Case 2.

The interviews have been semi-structured which has allowed me to follow a pre-established structure with some level of flexibility. The interviews have been face-to-face, in Swedish and ranged from 45 minutes to 1.5 hours, with an average of one hour. The majority of the interviewees have been male, due to it being a male-dominant industry. Different types of questions have been used during interviews. During the main part and especially in the beginning of the interview the questions have been open. Theory-driven questions have been used for example to find empirical examples of theory. Also confrontational questions have been used in some cases to present previous finding for communicative validation. Different types of questions represent different approaches to making implicit knowledge explicit and allow dealing more explicitly with presumptions (Flick, 2009).

Observations have enabled the collection of data regarding the current establishment of innovation culture, climate, processes and routines. The daily placement at the company has enabled both planned and unplanned participant observations which have included for example participation at meetings or collaborative activities. The observations have been unstructured, meaning no specific behavior was the focus (Hartman, 2004). Observations have been both descriptive, to get an orientation of the field, and focused to specific practices and processes (Flick, 2009).

Innovative workshops have been attended as well as facilitated during this project. Attending such workshops has enabled the collection of data regarding current innovative methods and climate. Facilitation of innovative workshops has enabled testing and validation of creative methods for PSS innovation.

Secondary data, such as internal documents, meeting notes, presentations, product development models and process maps have been collected throughout the project. These documents have been made and used by individuals at the company. Therefore they have formed the basis of the understanding of the case company's formal structures and processes.

4.4.2 Analysis of empirical data

During interviews, observations and workshops notes have been taken. Formal interviews were recorded, transcribed and summarized into a spreadsheet. Regular comparison of the longitudinal data has been made through the duration of the research project. The spreadsheet enabled a pattern matching analysis to find coinciding (or non-coinciding) patterns, which might have been difficult otherwise (Yin, 2003; Miles & Huberman, 1994). All interviews have been conducted in Swedish (their native language). When quotes have been used in publications, these have therefore been translated from Swedish to English.

During the workshops the facilitators appointed different focus areas for observations. Photos and notes were taken to document the process and results during the workshops. Right after the workshop both participants and facilitators evaluated whether the methods and tools had been

appropriate for the teams' specific challenges. The facilitators also had a discussion about their findings from their observations. We also drew energy curves on how we experienced the energy within the team during the workshop, which was also a way to reflect on the experience of the workshop.

4.5 Quality assessment of conducted research

There are many ways to assess whether or not a research is 'good'. The assessment of quality in research varies depending on if it is quantitative or qualitative research and to different methodologies that are used. Quantitative research quality is often related to measurements. Qualitative research seeks to describe, interpret and understand, and therefore needs other quality criteria. To some degree quality can be determined based on criteria of credibility, persuasiveness and verisimilitude. However, these constructs tend to focus on the quality of the report rather than the quality of the research (Feldman, 2007).

Since this research is based on case studies and uses the design research methodology (DRM) (Blessing & Chakrabarti, 2009), quality assessment criteria used by established researchers in case studies and DRM is therefore appropriate to assess the quality of the conducted research. Yin (2003) suggests four criterias for assessing the quality of case study research: (1) construct validity, (2) internal validity, (3) external validity and (4) reliability. Blessing & Chakrabarti (2009) discusses *verification* (5) of design methods and tools. This section presents and discusses these five criteria for assessing research quality in relation to their applicability for this type of research. Reflections on the quality assessment and how the assessment techniques have been used are later presented in the discussion chapter (7.3).

4.5.1 Construct validity

The question of *validity* relates to whether the researcher sees what they think they see, to specify the link of what is studied and the version of it provided by the researcher (Flick, 2009). Construct validity put emphasis on the development of appropriate measures for the concept that is being studied (Yin, 2003), do the observations or measurement tools represent the construct being investigated? Construct validity has to do with the research phase of data collection and composition.

For ensuring construct validity in case study research, Yin (2003) suggests the use of multiple sources of evidence, the establishment of a chain of evidence and to have the draft report reviewed by key informants. According to Feldman (2007) researchers should "*increase validity by combining multiple perspectives*" (Feldman, 2007, pp. 30). Therefore, in this research different data collection methods, such as interviews, observations and workshops in longitudinal, in-depth and cross case studies, have been used to ensure multiple perspectives

4.5.2 Internal validity – Trustworthiness

Internal validity regards the establishment of an underlying relationship, where certain conditions are shown to lead to other conditions (Yin, 2003). Flick (2009) suggests that one should ask how far

the researchers' constructions are grounded in the constructions of those whom they studied. Further, Feldman (2007) argues that it is not enough to say that it is true because it works, but also provide explainations or theory of why it works. Internal validity is according to Yin (2003) related to the data analysis phase (compared to construct validity that is related to the phase of data collection and composition).

The tactics suggested by Yin (2003) are related to the data analysis: to do pattern-matching, to do explanation-building, to address rival explanations and to use logic models. According to Feldman (2007) researchers should also provide clear and detailed descriptions of how their narratives were constructed from data.

Flick (2009) suggests the use of different types of triangulation enabled different perspectives on the issue to answer the research questions and to ensure appropriateness of the qualitative research. First, Methodological triangulation, e.g. using of different data collection methodologies. Second, Data triangulation, e.g. using of different data collection sources. Third, Theory triangulation, e.g. using different theoretical perspectives. Fourth, Investigator triangulation, e.g. using different observers/interviewers for a systematic comparison of different researchers' influences on the issue and the results.

In this research data analysis has been made with the use of pattern-matching technique, longitudinal comparison, workshop evaluation forms and by discussions between researchers. Further, different types of triangulation perspectives have applied to fulfill internal validity conditions.

4.5.3 External validity – Generalizability and transferability

The question of external validity regards whether the research can be generalized and transferred to other settings (Herr & Anderson, 2005; Yin, 2003). What we want ideally in research is theory that will apply everywhere and all the time, although this will never be possible (Easton, 2010). Even though the goal with qualitative research is not necessarily generalization (Flick, 2009), single cases are typically, criticized for offering poor basis for generalization. Yin (2003) argues that such critic implicitly contrast case study research to survey research, where survey research relies on statistical generalization, whereas case study research rely on analytical generalization. Analytical generalization relates to the striving to generalize findings to theory. Herr & Anderson (2005) similarily discusses two types of generalization, formalistic and naturalistic. Where formalistic is the traditional view on generalization, based on formal theory and codified data. Whereas, naturalistic generalization is based on narrative accounts with direct and vicarious experiences.

This research is focused on a single company which may provide marginal contribution to generalization but can provide other benefits. Eisenhardt & Graebner (2007) claim that "*single cases can enable the creation of more complicated theories than multiple cases, because single-case research can fit their theory exactly to the many details of a particular case*" (Eisenhardt & Graebner, 2007, pp.30). Single cases can provide a rich picture of a particular situation. Rich descriptions can unveil the dynamics of the phenomena and help identify similar dynamics in other cases, they act as

clear examples of what current theory have not captured "*We therefore can remember them longer and understand them more complexly than had they been presented as a thin description of a construct or as a statistical table*" (Dyer &Wilkins, 1991, pp. 617-618).

External validity of qualitative research and single cases are therefore rather a question of *transferability.* Transferability is dependent on the similarities between contexts (Lincoln & Guba, 1985). To make a judgment of transferability, one needs information about both contexts. Rich descriptions can therefore support transferability because it entails such information about the contexts; however it leaves the judgment to anyone else who interested in transferability (Lincoln & Guba, 1985). This research has focused on getting rich descriptions rather than quantitative data and therefore the question of transferability is more applicable rather than generalization.

4.5.4 Reliability – Recoverability

Reliability in its traditional sense regards if a repeated study of the object would come to the exact same results and conclusion. Although in qualitative studies, such as this research, it is problematic to assess *reliability,* since the object can undergo continuous changes. This research project has had the duration of four years, were continuous changes has taken place. Then reliability rather has to do with *recoverability* (Checkland & Holwell, 1998), which means that anyone can trace the steps of the research and thereby understand how the findings were established. This puts high demands on the methods for documentation and analysis in terms of thoroughness, clarity and carefulness. In this research project reliability requirements have been addressed with written documentation and methods of analysis.

4.5.5 Verification

Verification of design tools and methods are according to Blessing & Chakrabarti (2009) only achieved through successful application to practical design problems. This is the classical view of verification of design methods, although Buur (1990) argues that this is unrealistic for two reasons: (1) the design process is stochastic: "*a new design method may raise the probability of success, but does not guarantee it*" (Buur, 1990, pp. 3), (2) there are large number of influencing factors which make repitition virtually impossible. The innovation process at the case company is several years long and complex, hense it makes it very difficult to verify the success of applications. One method Buur (1990) suggests for verification of design theory is *verification by acceptance*, which means that the statements of the theory and the models/methods derived from theory are acceptable to experienced designers. This is a method that has been applicable for this research project. Acceptance further mean interaction with engineers over time, which deepens the understanding.

5 Summary of Appended Papers

Six papers are appended in this thesis, four have been presented and published at conferences and two are journal papers. The papers contribute to the overall results of the research. This chapter presents a summary of each of these papers. For more interest readers are directed to the appended papers. In the beginning of this chapter there is also a short description of how the papers are linked and an explanation of my contribution to each paper.

The purpose with this research is to advance the knowledge about the challenges and the support methodology of developing PSS innovation capability in the aerospace industry. Paper A sets the foundation of the challenges with PSS innovation in the aerospace industry. The study found that collaboration, internally within the company as well as externally, is a key factor for PSS innovation capability. External collaboration is addressed in paper B that is focused on university-industry collaboration since long-term transition is competence based. Internal collaboration is addressed in Paper C and E. Paper C focuses on key mechanism and methods/tools for PSS innovation. Paper D brings up the relation to traditional business model strategies, how to adapt business modeling tools specifically for PSS. Paper E focuses on organizational characteristics for PSS and supply chain effects. Paper F focuses on routines and activities for PSS innovation capability.

I have been the first author for all the papers. Descriptions of the distribution of work between the authors are presented in Table 6.

Table 6: Authors of the papers and the distribution of work between them

Paper	First author	Co-author(s)	Distribution of work between authors
A	J. Wallin	A. Larsson O. Isaksson T. Larsson	The initial idea to this paper came from Tobias Larsson. I did all the interviews and the analysis of the empirical data. Andreas Larsson and I wrote the literature framework. I was the head writer of the article, provided the draft of the paper and received contributions from the co-authors.
B	J. Wallin	O. Isaksson A. Larsson B-O. Elfström	Through collaboration with Delft University, we were informed about this special issue with the theme Designerly approach to networked innovation. The four authors identified the external collaboration with universities as an area where methods for creating a close collaboration had been developed. I lead the work made the complementary interviews; I did the literature framework and acted as the lead author of the paper. The other three contributed with their long experience of university-industry collaboration.
C	J. Wallin	I. Kihlander	Both of the authors were facilitators at the two workshops and collaborated with the creation of the workshops, the analysis of the findings and the writing of the paper. I was more experienced in PSS theory and foresight methodology, whereas Kihlander contributed more to creative methodology and problem-solving sessions.
D	J. Wallin	K. Chirumalla A. Thompson	The idea of this paper started when the three authors were doing a group work for a course assignment which resulted in this paper. I and Chirumalla were responsible for data collection. All three authors have been part of the analysis of the tool and the writing of the paper.
E	J. Wallin	K. Chirumalla O. Isaksson	I was the initiator of the paper and the main author. Chirumalla and I discussed the analysis and he also contributed with writing. Isaksson contributed with experience from the case company and the writing.
F	J. Wallin	V. Parida O. Isaksson	This paper is partly a development of a conference paper that I wrote and presented at the CIRP IPS2 conference 2012, although, this paper has a process view on the capability development. Parida contributed with his knowledge on Resources based view and we collaborated together with Isaksson in the writing and analysis of the data.

5.1 Paper A: Measuring innovation capability – Assessing collaborative performance in product-service system innovation

Wallin, J., Larsson, A., Isaksson, O. and Larsson, T. (2011). 'Measuring Innovation Capability – Assessing Collaborative Performance in Product-Service System Innovation'. Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems, Braunschweig, Germany

The purpose with this paper was to explore key indicators related to innovation capability in a PSS context. Previous work had identified *Customer involvement* and *Interaction between functions* to be of particular importance when developing PSS as opposed to developing 'only' products or technologies. Both describe collaboration and networking, the first focused on external collaboration, and the second focused on internal collaboration. Developing PSS changes the dynamics of collaboration, since the offering of a system involves a network of partners sharing the responsibility for a delivered function over a full lifecycle.

In particular, this paper focuses on describing aspects related to external and internal collaboration for PSS innovation. Seven types of innovative collaborations have been identified from the point of view of the cross-functional project team: *Collaboration within the department*, *with other departments within the business function*, *with other business functions within the company*, *with other companies within the group*, *with universities and research institutes*, *with suppliers*, *with customers* and *with customer's customer*).

The study highlights that since the company has a strong division between its service business, and the hardware/product development business on the commercial engines side, collaboration within the company as well as with new types of external partners needs development to become PSS providers. And within already established collaborations, the role and type of collaboration need to be improved. It is evident from the military side that the unique and tight connection to the customer is more mature and one success factor to the service integration of the product offers.

Furthermore, some conditions were found that need to be considered in developing new types of innovative capabilities at the case company:

- Since services are consumed by airlines, the relationship with the OEMs need to evolve.
- Aerospace regulation and long life-cycle of products and business contracts may act as conservation mechanism when introducing new innovation models.
- Long term customer relation is significant for building trust and reducing risk in new innovations with service content.
- True exploitation of internal and external capabilities to combine service expertise and hardware expertise require senior level ambitions and directives since the established way of working does not naturally have this focus.
- Common business focus within different functions supports internal collaboration

Measuring innovation is one way that would provide useful insights and facts on how innovative the company is before the product or service has reached the market. The article discusses how to assess the collaborative performance for innovation, taking into account both activity and effect measures and a combination of qualitative and quantitative measures. The activity metrics aims to measure the degree of collaboration, where more activities would indicate a more active collaborative work. It is also important to not only measure established partner collaboration, but also the collaboration with partners contributing to future PSS solutions, such as universities, as well as new suppliers and customers.

The effect measures are expected to show change over longer time. Most important is to include the PSS aspect into the customer satisfaction measures already conducted. Quantitative effect measures include pure counting of ideas, business proposals and concluded new businesses.

5.2 Paper B: Bridging the gap between university and industry – Three mechanisms for innovation efficiency

Wallin, J., Isaksson, O., Larsson, A. and Elfström, B-O. (2014). 'Bridging the Gap between University and Industry: Three Mechanisms for Innovation Efficiency'. Accepted for publication in the International Journal of Innovation and Technology Management's special issue on Exploring a designerly approach to networked innovation (to appear 2014, Vol. 11, No. 1).

PSS innovation involves an increased collaboration with external partners. This type of collaboration between two different organizations involves people with different competences, knowledge, experiences and points of view, which is important for innovation. A network with competence suppliers can complement the in-house competence of the company and enrich the internal environment. However, there is a gap in the contextual understanding between the people from the two different organizations. It is crucial to ensure efficient communication as difficulties arise regarding resolving issues, misunderstandings and preconceptions. In order to understand the different perspectives of the university-industry collaboration and create a stable long-term collaborative relationship there is a need to create a collaborative culture, common meeting places and effective communication. This article focuses on the following two research questions: *How can a company overcome the contextual barriers and gain a mutual understanding between people who do not work in the same organization?* And; *What are the mechanisms that contribute to a working collaboration between universities and industry?*

One type of external collaboration that has been proven successful for the company is the collaboration with academia. This paper describes the company's long-term experience of university-industry collaboration and explores the challenges and success factors for this collaboration. There are several reasons for the company to collaborate with universities: first, it supports the recruiting process at the company; second, it creates a stable partner for research initiatives; and third, it is a source for innovation. However, industry and academia have different drivers. For example, academia has a more long-term view of their work, while the company's is more short-term.

The paper presents a model of collaboration that addresses the barriers in three dimensions: strategic, tactic and operational in order to capture both the long-term and the short-term perspective. In combination is the designerly approach to give an illustrative, contextual and interactive perspective to networked innovation, that focuses on iterative and non-verbal tools and on solutions rather than problems in order to overcome barriers for a shared understanding between people who are not working in the same organization. For successful networked collaborative environment between academia and industry it is considered important to facilitate understanding, co-creation and ideation. To do so, this paper includes three designerly inspired mechanisms that have been developed and used in the company and contribute to a working collaboration between universities and industry. First, the Technology Readiness Level (TRL) which is a visual scale that explains abstract maturity relations; second, workshops, that result in an instant contribution to communication and sharing among participants; and third, prototyping that visualizes and communicates ideation.

5.3 Paper C: Enabling PSS development using creative workshops – Experience from industry cases

Wallin, J. and Kihlander I. (2012). 'Enabling PSS development using creative workshops: Experience from industry cases'. Proceedings at the International Design Conference – DESIGN 2012, Dubrovnik, Croatia, May 21-24.

PSS opens up the problem space since the solution to the problem does not only concern the design of a product, but also includes the design of services. However the integration of services in manufacturing industries challenges the established way of working at the companies (Mont, 2002) since there are differences between the way products and services are produced, delivered and consumed (Brezet et al, 2001) and developing PSS involves integrating expertise from both service and product development.

The purpose with this paper was to contribute to the understanding of the challenges companies and their PSS teams face, and to test creative workshop methods that could support the teams in the early phases of PSS development. The research question for this paper is: *How can PSS development be supported by creative workshop methods?*

In this paper a number of creative methods were selected for testing in two actual industrial cases, with teams working on PSS issues. The first case was a business-to-business (B2B) company in the aerospace industry and the second was a business-to-consumer (B2C) company in the automotive industry. The selected methods were chosen since they were found to respond to the challenges of developing PSS.

The differences of products and services found in literature characterize PSS (first column in Table 7). The literature study and discussions with the industry partners identified the challenges and needs of the organizations and their teams (second and third columns in Table 7). Creative methods were chosen for the workshops to address the identified challenges and needs (column four in Table 7).

This study shows that creative workshops can be seen as an enabler for PSS innovation through the creation of a creative environment that enables a common understanding, knowledge transfer and creative ideation. The research points to the fact that creative methods, such as Janus Cones, Personas and Prototyping which were tested in this study, are means that contribute in handling the PSS challenges of the teams. Further, in order to achieve successful employment of such creativity methods in PSS development it is important to ensure that the right participants are present, that the topic is relevant for the participants and that the design of the workshop suits the specific topic. Further, the study indicates similarities in the PSS challenges for two teams from two different industries.

Experiences from the two cases have implications for facilitating PSS innovation workshops. It was found that it is especially important to pay extra attention to certain factors when conducting such workshops (compared to product development in a traditional sense). First, it is important to visualize time perspectives, since the time perspective can differ between products and services, i.e.

select a creativity technique that enables this visualization. Second, the sampling of participants is important, since PSS involves expertise from both product development, service development and business development, which can require new team constellations within established organizations. Third, the focus needs to be on customer needs and the creation of customer value, in order to combine the values from both products and services. And fourth, the making of prototypes was successful, even though the facilitators had expected more difficulties prototyping PSS compared to prototyping tangible products.

Table 7. Framework addressing PSS challenges (Paper C)

Characteristics of PSS Origin: Literature	**Challenges for organizations** Origin: Literature + discussions with case companies	**Needs of organizations** Origin: Literature + discussions with case companies	**Methods chosen** Origin: Selection made by the research team in the pre-planning phase
Time perspectives	The transition towards PSS challenges the adaptability of the organization	Visualize history and future opportunities	Janus Cones
	The product is produced and used at different times, services are produced at the time they are used	Visualize time	Janus Cones
Ownership	Products and services are developed by different areas of expertise	Distributed participation	Purposive sampling of participants
	PSS reaches many areas and stakeholders	Identify stakeholder and their needs	Identification of stakeholder and their needs
	The designer of the service enables the client/user to participate/co-produce the final solution	Understand the customers/users and their needs	Personas /Future Users
Design	PSS focuses on providing value for both customer and enablers	Identify stakeholders and their needs	Identification of stakeholders and their needs
	PSS focuses on providing value in use to the customers rather than fulfilling technical requirements	Understand customers' needs	Personas/Future Users
	PSS include both the tangible product and intangible services and both hard and soft variables	Visualize value creation	Prototypes

5.4 Paper D: Developing PSS concepts from traditional product sales situation – The use of Business Model Canvas

Wallin, J., Chirumalla, K. and Thompson, A. (2013). 'Developing PSS Concepts from Traditional Product Sales Situation: The Use of Business Model Canvas'. Proceedings of the 5th CIRP International Conference on Industrial Product-Service Systems, Bochum, Germany, April 14th-15th, 2013.

With the unprecedented speed at which customers' needs and behaviors are changing, a company's ability to rapidly adapt or generate innovative business models is critical to success. Business model innovation has become important for organizations to rethink their value creation process and identify new ways to create value for their customers and themselves. One recent tool for developing new business models is "The Business Model Canvas" (BMC) that can be used to systematically understand, design and implement a new business model (Osterwalder & Pigneur, 2010). Current research on PSS provides little guidance regarding the development of new business models for companies in the transition towards PSS development and there has been little research conducted on using BMC for PSS design.

This paper aims to fill this gap by answering the following research question: *How can the Business Model Canvas support a company in developing PSS concepts in the early phases of the transition towards PSS development?* This study evaluated the use of the Business Model Canvas in developing PSS concepts especially with respect to manufacturing companies seeking to transition towards PSS. The paper proposes an approach using the BMC, which could help manufacturers in the transition towards PSS development by articulating the key business elements in developing and analyzing the PSS concepts from their traditional sales situation. The Business Model Canvas is a tool for describing and visualizing the existing business models or for developing new ones. The visual canvas describes the business model through nine basic business elements: (1) Customer Segments, (2) Value Proposition, (3) Channels, (4) Customer Relationship, (5) Revenue Streams, (6) Key Resources, (7) Key Activities, (8) Key Partners, (9) Cost Structure.

At the case company the BMC is not a well-known tool, but it has been used in some groups for business development and PSS development groups. The tool has been used both as a workshop tool, where the group has performed a brainstorm activity for each section, as well as by individuals building a business case. For this study data has been collected from observations and semi-structured interviews with stakeholders in PSS development and business development, where some have used the BMC in their work. From the empirical discussion, Table 8 summarizes the evolution of business model elements for PSS concepts from the traditional product sales situation.

This study found that Business Model Canvas is a promising tool for the companies to rapidly analyze and discuss their traditional product sales situation, since the tool is intuitive and easy-to-use and supports the modifying or creating of new business models at a faster pace. By having a value proposition as a central position, BMC provides an overall view of "what" and "how" the business would look like in the transition towards PSS development. Having an initial emphasis on the value proposition, may aid companies in taking that mental break from their product and getting a "PSS mindset".

Table 8. Evolution of business model elements for PSS concepts from traditional situation

Business Model Canvas Elements	Traditional product sales situation (product-oriented)	PSS concepts (service-oriented/ use-oriented)
Customer Segments	Engine OEM of the product supply chain in aerospace industry	Potentially new customers in aerospace industry. E.g. airlines, aircraft manufacturers.
Value Proposition	-The value of the product functionality and light weight technology -The value of the add-on services for product functionality	Added value from the component contribution to overall system performance service; value of risk reduction, safety increase, and cost reduction
Channels	Partner programs	Partner programs or Joint venture
Customer Relationship	Strong ties to closest customer (Engine OEM for products, airlines for services) and weak ties to other stakeholders in the network	-Strong ties to various stakeholders within the industry who are affected by the functionality of the product; Dedicated technical assistance and co-creation in early phases
Revenue Streams	-Percentage of engine revenue -Service contracts - Revenue on spare parts sales	Integrated product-service contracts, availability contracts and licensees
Key Resources	-Product and production knowledge -Patents -Financial -Contracts	Added key resources: -Cross-functional knowledge - Relationships with extended collaborators
Key Activities	-Development & manufacturing of product -Service development & provision -Assign responsible positions	-Integrated product-service system development; Calculating life consumption; Monitoring product environment
Key Partnerships	-Customer and suppliers in the aerospace industry -Academia	Extended stakeholder network through joint ventures, e.g. IT partners, service centers.
Cost Structures	Development; Material and production; Service provision; Entrance fee in the engine programs	Added cost of ensuring uptime, software development, monitoring costs and IT delivery.

This paper suggests some modifications to the BMC in order to be a tool to support the transition towards PSS development. First, it needs to have a clearer focus on this change, emphasize a change in perspective and to widen the business scope. For example, instead of only asking: *What value do we deliver to the customer?* and *For whom are we creating value?* We should also ask: *Are there additional customer needs that we could be satisfying?* and *Who could be benefitting from the value we are creating?* Second, the BMC tool needs the addition of business risks, since the transition towards PSS development involves taking new risks. This could either be done by adding a new element of *Business Risks* to the BMC or with additional risk questions in each of the nine existing business elements, for example: *What are our principal business risks in PSS transition? How do we integrate risks with the company's strategic direction? How effective is our process for managing risks?*

5.5 Paper E: Enabling organizational changes for development of product-service system offers

Wallin, J., Chirumalla, K. and Isaksson, O. (2013). 'Enabling organizational changes for development of product-service system offers'. Proceedings of the 19th International Conference on Engineering Design (ICED13), Seoul, South Korea, August, 2013 (Reviewers' Favorite: rated in the top 10% papers based on reviewers' scores)

Product-Service Systems development differs from traditional product development since services are part of the solution. This paper addresses what consequences this has on manufacturing organizations. There are different types of PSS offers, from product offers that include services as "add-on", to the sale of services that include tangible goods as "add-on" (Clayton, et al., 2012; Olivia & Kallenberg, 2003). Previous research on organizational changes for PSS has regarded PSS offers in general, but not gone into detail regarding the differences between different types of PSS offers. This study has taken the following research question to guide this investigation: *How does a manufacturing organization need to change in order to better suit to the development of different types of PSS offers?* The case company offers different kinds of PSS offers in their military and commercial business sides in order to differentiate with their competitors and to offer unique customer value (Figure 7), thereby placing themselves at several positions in the PSS continuum, although they have continued to have a focus on physical products in the engineering organization.

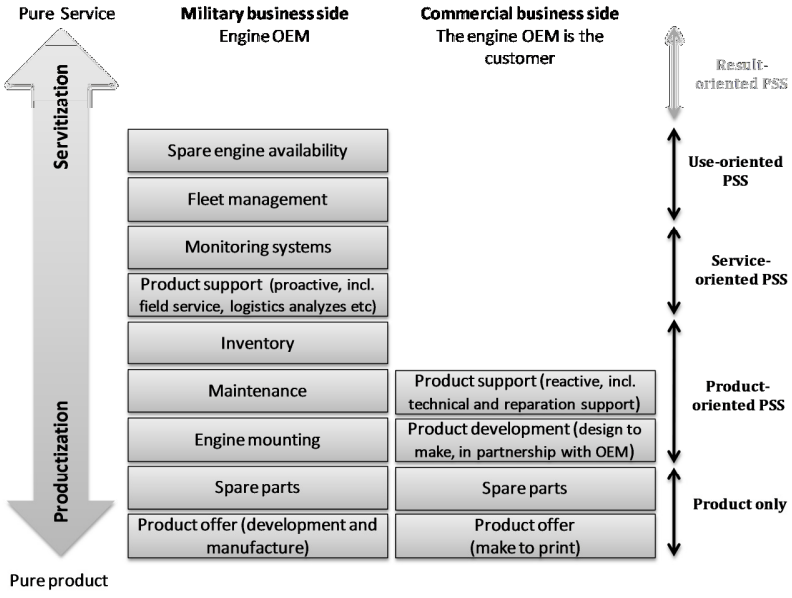


Figure 7: Classification of existing PSS offers at the case company (Paper E)

This paper shows that depending on the type of PSS offer that the organization is aiming for, different organizational changes have been identified under four dimensions: (1) Business strategy and decision making, (2) Internal organizational structure, (3) Team composition, and (4) External networks and customer relationship (Table 9).

PSS needs strong ties between service and product development organizations and the expertise within to ensure information flow between service and product development. There are, for example, opportunities for the service division to provide input to product development and vice versa. One way to ensure ties and enable trust and support is to have stakeholders in the interface between the divisions or an incorporation of service development competence in the product development project.

Table 9. Organizational changes with different types of PSS

	Product only	**Product-oriented PSS**	**Service-oriented PSS**	**Use-oriented PSS**
PSS case example	*Product offers*	*Product offers including e.g. maintenance services*	*Product offers including e.g. monitoring systems*	*Product availability contracts such as 'Power by the hour'*
Business strategy and decision making	e.g. product quality or product development efficiency	e.g. dedicated customer support to increase the response and improve the relationship	e.g. value creation strategy e.g. "Soft product"	e.g. long-term commitment to offer unique value
Internal organizational structure	Product development and manufacturing	Products and services are developed in separate departments	Products and services are closely linked in development and PSS teams develop products, services and software	No borders between product and service development since products are sold as services
Team composition	Cross-functional project teams with product development and manufacturing expertise	Minor collaboration between service and product development	Higher degree of cross-functionality in the development teams including service expertise, product expertise and business model expertise	Higher degree of cross-organizational teams with participants from different product lifecycle phases and a stronger focus on business model expertise
External networks and customer relationships	Few interactions with the customer (which not necessarily is the product user) at e.g. the sales situation	Interactions with the customer (and product users) through the product life cycle based on the customers demand	Close contact with customer (and product users) to receive information from e.g. product usage	Interactions with customers (and product users) through the whole product life cycle for co-creation and co-development

The study found that addressing the challenges related to organizational changes, such as the business strategy, the internal and external network structure, and team composition, are crucial steps forward in the PSS transition of a manufacturing organization. The changes to PSS development involves taking in a wider scope of development as the borders between products and service development vanish in the organizational structure, integrated development involves complex interactions and networks and therefore puts new demands on the individuals in such an organization.

5.6 Paper F: Building product-service system innovation capability in manufacturing industry: A process view on capability development

Wallin, J., Parida, V. and Isaksson, O. (2013). 'Building Product-Service System Innovation Capability in Manufacturing Industry: A Process View on Capability Development'. Revised and re-submitted to Journal.

Manufacturers strive to ensure competitiveness by providing PSS for increased customer value on their offers. This change implies new organizational need for possessing necessary capabilities for the development of innovative PSS offers. The purpose of this paper is to advance the understanding on how manufacturing companies can build PSS innovation capability as they transform from being product provider into PSS provider. Capabilities research has its origin in the resource-based view literature (Helfat & Peteraf, 2003; Teece, et al., 1997) that argues that competitiveness is related to development of valuable and unique capabilities. This paper argues that the presence of PSS oriented routines and capabilities enables the organization to effectively ease the challenges and improve their ability to benefit from PSS offers, and thereby gain competiveness and success of the company. Since significant changes need to be introduced in the transition towards PSS innovation, early phases of development are important for PSS innovation capability development. New competences and routines have to be modified to account for the new necessary capabilities.

This paper explains the characteristics associated with different PSS innovation development phases and links specific internal routines to these PSS development phases. 'Actions', are the steps in a process of accomplishing a specific task at different organizational levels to provide insights into the development of the routines, and organizational 'routines', are the repetitive, recognizable patterns of independent actions, which are the building block for capabilities. Internal routines and actions at different organizational levels are exemplified in the paper during different PSS development phases. This paper shows the internal routines that effectively have mitigated the challenges of developing successful PSS offers. Different phases of PSS development have shown different challenges and therefore accounted for different routines, which have been the building blocks of the PSS innovation capabilities that have been developed over time at the case company. To support these routines actions have been taken at different organizational levels: team level and organization level, which contribute to a better understanding of the capability development of the company as a whole organization. Thereby this paper contributes towards two bodies of literatures; the PSS literature as it addresses the "black box" of what factors differentiates successful PSS providers from unsuccessful PSS providers by proposing PSS innovation capabilities as a central factor, and to the resource-based view literature as it empirically examines how large manufacturing companies develop PSS innovation capabilities.

The idea phase in PSS development can be more complex since the ideas need to be found on a higher level of abstraction when innovating at a system level (Brezet, et al., 2001). This case study found that the challenge regarding the rise of innovative PSS ideas in the need phase should be met with the establishment of an innovative PSS culture and continuous customer interaction. In line with Morelli (2003), this study also indicated the importance of interaction, collaboration and

communication, internally between disciplines as well as externally with customer, to a higher degree compared to product development. This can be handled with routines for promoting cross-functionality and involvement of partners. PSS capability also involves the development of new competence (e.g. Isaksson et al, 2009), and establishment of PSS business. The paper presents a process model of PSS innovation capability development that includes routines and activities from the findings of the research.

6 Key Findings

This chapter presents the key findings related to the three research questions.

6.1 RQ1: How can collaboration enable PSS innovation capability development?

As services development is integrated with the product development the need for new forms of collaborations become important to ensure that different expertise are combined to create competitive PSS offers. Not only the collaboration between product development and service development, but also, a closer relationship with customer becomes essential and there is also a stronger need for involvement of network partners. In this research, we found empirical support for different types of internal and external collaborations, such as internal collaboration within a team/department, between teams/departments, between business areas; external collaboration with customer, suppliers, academia and customers' customer which has shown to be relevant for PSS innovation.

This research has focused on different types of collaborations, within a PSS team, between departments, organizations (e.g. customers and suppliers) and institutions (e.g. universities). Moreover, creating a common understanding between people from different competence areas and organizations was found to be a central condition for effective PSS innovation collaboration. In addition, this research has found four ways that collaboration can enable PSS innovation capability:

1) By considering the differences in time perspectives in the collaboration

More specifically, this research has identified three challenges that are related to the difference in time perspective between individuals that need to collaborate for PSS innovation: (I) life cycle perspective, (II) maturity of the way of working, (III) maturity of the technology. These three challenges are all related to time perspectives in different ways.

I) *Life cycle perspective*: The perspective on the life cycle changes in the transition to PSS innovation. When the offer only includes a product at the case company ('make to print') the time span is focused on order to delivery. This life span changes when services are included (e.g. technical support, development services, maintenance, monitoring systems), since the use phase is then included. These new conditions related to time perspective hold important implications for early development phases. When people from both service and product development need to collaborate, they are challenged by these different perspectives on the life cycle (PAPER C).

II) *Maturity in ways of working*: Manufacturing companies have a longer history with product development as compared to service or software development in the industry. The traditional way of

working is therefore more mature and prominent. At the case company, the focus on product development has been evident from the start of the company (1941), whereas the history of engine maintenance services reaches back to the 80s and software development to the late 90s. The PSS teams are therefore challenged by the different maturity in their ways of working. The established way of working in product development, with mature methodologies for analyzing, testing and validating product functionality, are not applicable for analyzing, testing and validating services. PSS innovations are in larger degree dependent on the collaboration with the customer to analyze, test and validate the innovations. Although, such collaboration and way of working was found to be more established and mature in service development, especially at the military business side at the case company (PAPER, A and F).

III) *Maturity of new technology*: When new technologies are introduced, which is often the case in PSS innovation context; there is a different time perspective between research/technology development and implementation in product development. In this research we have studied the Academia-industry relationship which is challenged by this. Academia, focused on research and technology, have a long-term view compared to the short-term view of implementation in product development in the industry (PAPER B).

Thus, in this research we found that these three different time perspectives affect and challenge the PSS collaboration both internally and externally, since people with different perspectives on time need to collaborate in the creation of new innovative PSS offers. To handle the challenge of collaboration and enable PSS innovation capability a common understanding between individuals and organizations is needed and therefore these different perspectives on time need to be understood. This means that to build a long-term relationship and at the same time address short-term issues different time dimensions need to be considered. This research has further shown that these time perspectives can be addressed with appropriate methods/tools that clarifies/visualizes the life cycle perspective, the maturity in ways of working of the participants and the maturity of the technology/innovation that is under development (further described in the next RQ). It was evident from the observations, evaluations and interviews that the visualization of time perspective contributed positively to a common understanding.

2) By taking into account the type of PSS for the collaboration

This research also found that the collaboration not only needs to change as the company transitions from PD to PSS, but the collaboration is also affected by the type of PSS. As more services are integrated in the product offer (further to *pure service* side on the PSS continuum), the higher is the need to interact with customer. From a PSS offers perspective, this may include maintenance services or a re-active product support, where the company needs to receive information from the customer to provide this type of product-oriented PSS. In PSS offers that include monitoring systems and/or pro-active product support, the company needs a continuous information flow during use, not only when something goes wrong. The co-creation with the customer to create the PSS intensifies as more services are incorporated to the product.

The dependency on type of PSS is also evident in internal collaboration. The more services are integrated, the greater the need becomes for different types of competence/expertise to collaborate internally more frequently. This research found that at the case company there was a low degree of information flow between, for example, product development and technical product support, while at the development of a monitoring system, there was not only information exchange, but also co-creation. In other words, the more services are incorporated (for more complex PSS development), the greater is the need for the departments of service development and product development to be integrated and the greater the cross-functionality needs to be in the teams. This cross-functionality also needs to be visible in the PSS development teams and in PSS innovation activities such as workshops.

3) By continuously using the collaboration as a means to create knowledge about the customer

The need to interact with customer is evident during the whole PSS life cycle, from idea-phase to use-phase. During early phases of PSS innovation, the interaction with customer it is important to understand customer needs and to inspire idea generation and during use-phases it is important in order to receive information regarding the usage. This interaction creates knowledge about customer needs. At the case company, it was found that the knowledge about customer needs, that went deeper than a requirement specification, lead to the PSS innovation LTS (Life Tracking System), a monitoring system that calculates life consumption of engine components (Case 2, PAPER F).

4) By handling the challenges of the supply chain position in the collaboration

Supply chain position also affects the ability of a company to develop capability for offering certain types of PSS. This research has compared two separate situations, Case 1, where the company acts as a first tier supplier on the commercial business side, and Case 2, where the company is OEM of the military aircraft engine. As a first tier supplier, the company cannot position themselves as a competitor to their customer that can offer the same type of PSS. The company is therefore limited in PSS offers that retain their relationship with customers. A pragmatic way is to define e.g. Product Development itself as a service to the OEM. On the military business side, as an engine OEM, the company has more freedom with developing and offering PSS.

6.2 RQ2: How can support methodology enable collaboration for PSS innovation capability development?

Appropriate methodology can support creation of structure to systematically address the challenges and opportunities for PSS design teams in the transition from product development to PSS development. When working with methods for PSS innovation it is important to consider the different characteristics of products and services. This research builds on previous research on the different characteristics of products and services, and shows how to handle the challenges that arise due to these differences through applying appropriate methods. In this research we have tested creative workshop methodology which contributes to a better communication and collaboration leading to new innovation outcomes. This research found that to facilitate PSS innovation in a workshop, there is a need to focus on the interaction between participants and systematically

addresses the challenges of PSS innovation and collaboration. During our workshops we addressed challenges related to (1) time perspectives, (2) stakeholders need and customer value and (3) both hard and soft variables with positive results. This research further gives examples of workshop tools/activities to address this systematically (for example *Janus Cones*, *TRL-scale, Personas, Stakeholder Identification* and *Prototypes*). Apart from creative PSS workshop activities, this research has also analyzed a tool for creating business models for PSS (4):

1) The time perspective is different in product development compared to service development (as described in the previous section). Therefore, as this research found, there is a need for the PSS design team to clarify and visualize the time perspective in order to develop a common understanding of the different areas. *Janus Cones* was used in this research as a means to make time perspectives explicit in the PSS collaboration. Through observations at workshops and evaluations after workshops, it was found that the Janus Cones was a popular activity at the start of the workshop. It contributed positively to the common understanding and collaboration within the team. The participants got immediately engaged in sharing their views and knowledge of the history and foresight of the problem which created a common understanding within the team in the workshop (PAPER C). Further, the *TRL-scale* has also been used at the case company. In this research the *TRL-scale* was shown to put emphasis on the time perspective of the development processes in research/technology/innovation development which also contributed to a common understanding of the time perspective (PAPER B).

2) The stakeholder needs and customer value are important to address in PSS innovation since the ownership requirements and conditions of products and services are different. Ownership of a product is transferred when the product is sold, which is not the case for services. The ownership and responsibilities are therefore more complicated for PSS. Therefore, as this research shows, it is important to have increased contact and collaboration with partners, customer and user of the PSS. It is further important to put increased emphasis on the sampling of participant and new team constellations with greater cross-functionality, since PSS involves expertise from both product development, service development and business development. Creating Personas or Stakeholder identification were shown in this research to be effective activities in the workshop since they put the focus on creating customer value and created a valuable discussion on how to create customer value (PAPER C). Furthermore, the research shows that it is important to focus on customer needs and creation of customer value to a greater extent compared to traditional product development. The more services are integrated into the product offers, the more the company has to focus on value creation for the customer and to widen the scope of what creates value.

3) Both hard and soft variables are involved in PSS innovation since the design of products and services are different. Products have hard technical variables, such as material, dimensions etc., whereas services include soft variables, such as a time and place etc. Therefore, as this research shows, there is a need to visualize not only the product but also the services, software and the combination in a complete offer. Building prototypes of the PSS innovation offer has in this research (through interviews and observations at workshops) (PAPER B and C) shown useful for several reasons:

- to visualize hard and soft variables
- to stimulate communication
- to create ground for unifying the group
- to visualizes specific challenges with the offer
- to visualize what is otherwise just seen on the computer
- to get a "feel" of the offer
- to help the ideation of new ideas

4) Creating business models for PSS is part of the transition towards PSS innovations. A well known tool for business modeling is The Business Model Canvas (BMC). This research has shown that the BMC is an appropriate tool for PSS since it focuses on value creation and customer relationship, however, this research further found that it lacks an emphasis on change which is needed for PSS transition and it lacks a focus on risks which is of importance in the PSS transition. The tool therefore needs to be complemented with activities that pushes for change and identifies/addresses risks, when used for PSS innovation. When used at the case company, the BMC has therefore been complemented with an activity of risk assessment which was found to be needed (PAPER D).

The innovation process is very long in the aerospace industry, longer than a PhD project. The effect of these PSS innovation activities could therefore (in this research project) not be measured on the success of the PSS on the market, but rather on the immediate affect perceived during and after the activities. Although these workshop and business model methods/tools are not designed specifically for PSS, they have in this research been tested and/or analyzed in a PSS context in industry with real PSS teams and found to be valuable.

6.3 RQ3: How can PSS innovation capability be developed?

Both internal and external collaborations are needed to build PSS innovation capability since it involves a combination of internal actors and often PSS is developed in co-creation together with the customer/user. The capability development is further supported through methods that create a structure to systematically adress the PSS challenges. This research therefore supports the theoretical framework of PSS innovation capability development presented in section 3.1 (Figure 4).

The capability of an organization is important for its long term success. This thesis argues that to successfully create new PSS innovations on the market repeatedly, the company needs to develop PSS innovation capability.

1) By establishing routines and activities

Generally, routines and activities are building blocks for capability development. This research has lead to identification of specific routines and activities that build PSS innovation capability (PAPER F). Furthermore, this research has taken a longitudinal perspective on development of PSS capability by linking development of PSS routines with challenges related to different phases of PSS innovation development. Specifically, this research has studied the early phases of PSS innovation: (1) Need

phase, (2) Solution seeking phase and (3) Solution development phase. For example, during the need phase, routines related to customer interaction and innovative organizational climate were found to be established. In the solution seeking phase routines related to cross-functionality and network partnering were created. Finally, in the solution development phase, routines, related to competence development and business case development, were established. Further, routines and activities to build PSS innovation capability are related to all levels within the organization.

2) By capitalizing on product knowledge

PSS innovations that are based on the manufacturers' product knowledge cannot easily be copied. The required product knowledge creates a 'barrier of entry' to competitors that do not have this specific knowledge. This research has recognized the successful process of transferring the product knowledge of the company into new service offer (Case 2). The development of a monitoring system for calculating life consumption of the engine component (LTS) is one example of a PSS innovation that would not have been possible neither to develop nor to provide without access to the underlying product definition, engineering understanding and knowledge of the product. Competitors have not been able to compete with this PSS innovation since they do not have the knowledge base. This research has exemplified how a manufacturing company can create PSS innovation by capitalizing on their product knowledge, which allows for reduction of risks, compared to complete service strategies.

3) By strategic alignment

The transition towards PSS is a slow process although the case company has a long history of interest in PSS, starting from the late 1990's. The company has understood the importance of building competence for long term success. However, the findings of this research show that when the company is new to these kinds of PSS offers, the emphasis is put on the capabilities and competence of key individuals. Therefore, it has also been important to support PSS innovation with the implementation of PSS strategies to build the PSS innovation capability of the whole organization. The company had (during Volvo times) a 'soft product' strategy. These two factors, building PSS competence and implementing a PSS strategy, have in this research shown to be crucial for the PSS innovation capability development.

7 Discussion and Conclusion

This last chapter of the thesis discusses and concludes the key findings in relation to the theory and provides practical guidelines for industries that aim to build their PSS innovation capability. The chapter further includes reflection on the quality of the research and ends with suggestions for future research on the topic and concluding remarks.

This research has studied the aerospace industry, where the OEMs are increasing their operational services and at the same time increasingly outsources their product development to first tier suppliers, such as the case company on the commercial business side. As the trend of outsourcing product development continues, the product knowledge is increasingly transferred to first tier suppliers and the OEMs keep the responsibility of technology integration, assembly and operational services. This change in the aerospace industry implies the need of new capabilities for the first tier suppliers. The need for innovation capabilities based on product knowledge and service integration that fill the gap to the operational services provided by the OEM. This research presents this industrially relevant trend, which is a rare case in PSS literature, thereby important, and call for further research.

The transition towards PSS development is more than a change of business models for a manufacturing company. It is a significant transition of the entire organization that involves new collaborations, new ways of working and another mindset. The thesis argues that to be able to become a successful PSS innovation provider in the long run, the organization needs to develop capability for PSS innovation. To build such PSS innovation capability routines and activities are needed as well as support methods and a focus on internal and external collaboration.

One limitation of this research has been that it is mainly focused on one single company. On the other hand it builds on a unique qualitative longitudinal case study. The closeness to the case company, as an industrial PhD student, has allowed for a deeper understanding of the challenges for PSS innovation as well as the testing and analysis of PSS innovation methods in a real-life PSS context. The case company is also empirically valuable due to its dual positions in the supply chain depending on business area (from a subsystem provider to a OEM); it offers different types of PSS offers (which has allowed studies of PSS in general as well as specific PSS types) and it has a long history of interest in PSS which has involved the creation of PSS innovation capability.

Increased focus on engineering design perspective has been needed to develop the methods and tools for PSS innovation capability support. Since the focus has been on PSS innovation, although not

limited to a specific type of PSS, the results should be evaluated in this context even though specific methods could be relevant also in pure product or pure service development context.

7.1 Theoretical implications

This research project has aimed to contribute to the research literature of product-service systems. However, to advance the PSS literature, it needs integration with other literatures. In this research project literature on innovation management, organization theory and capability have been explored in relation to the PSS literature, which has enriched the knowledge of research phenomena.

PSS literature has identified different types of PSS (Tukker & Tischner, 2006; Clayton, et al., 2012; Olivia & Kallenberg, 2003). However, when describing the transition it has not been significantly clarified that the aim might not necessarily be to reach the furthest on the scale to offer *pure service*. The aim might as well be to *just* reach product-oriented or service-oriented PSS, or to be at several positions at the same time. Despite the particular aim of type of PSS offers, the ultimate aim must still be to build the innovation capability for this/these PSS type(s).

PSS literature is full of examples of cases where the companies have transitioned from one position on the PSS continuum (Tukker & Tischner, 2006; Clayton, et al., 2012) to another, by adding service offers to their traditional product offers. The case company is an example of a company that provides different types of PSS offers and positions themselves on several places along the PSS continuum. This shows the complexity in the ways of working for the manufacturing organization and this complexity in PSS offers has rarely been empirically exemplified in literature. Further, the case company also provides insights about how the variety in PSS offers is dependent on their position in the supply chain. As an engine OEM on the military business side, the variety of PSS offers is greater, compared to their position as a first-tier supplier of engine components on the commercial business side.

Vargo & Lusch (2004) recognized the service knowledge needed to provide services, but failed to recognized the link between product knowledge and service provision. Manufacturing companies with their history of developing and offering products, naturally have advanced product related competence and ownership of product information. In PSS literature there are examples of companies that have change their business models, from a product focus to a service focus, for example IBM (Dittrich, et al., 2007). IBM outsourced their hardware technologies (which at the time were their core competence) to concetrate on software and services instead. Such companies thereby take large risks because the change is not founded on the core competence of the company and thereby they need to develop new core competence. Although IBM is a success story, other companies might not be as fortunate. Offers that are not based on core competence are more easily copied. Manufacturing companies with a history of developing the product, have their core competence in product development. This research exemplifies how manufacturing companies can rely on their specific product knowledge (their core competence) in the creation of new PSS

innovations. This research therefore contributes to the PSS literature by exemplifying how companies can enhance their chance to gain from a PSS transition without taking large risk.

Previous PSS literature has expressed the need for well established methodology for PSS development (Vasantha, et al., 2013). On the other hand, the methods and tools to support creativity and innovation presented in innovation management and design engineering literature are plenty (McFadzean, 1999; Shneiderman, 2007). The innovation literature can provide substantial contribution to the PSS literature in terms of creative methodology. The different characteristics between products and services have been identified in PSS literature by Morelli (2003) and Brezet, et al. (2001). These charecteristics can represent the differences in time perspectives (e.g. products are produced then used, whereas services are used and produced at the same time), ownership (the ownership of products is transferred when they are bought, but the ownership of a service is not transferred) and design (hard technical variables of products, soft/intangible variables of services. This has formed the basis for the development of methods and tools in this research. Martinez, et al. (2010) highlighted the need to create a common language between stakeholders and suggested workshops as an appropriate method for this purpose. This research has exemplified key characteristics and tested appropriate tools for such a workshop (PAPER C). This research focuses specifically on PSS innovation. The research has exemplified the challenges of PSS innovation and further analyzed and tested creative methodology for PSS innovation in workshops and business modeling to support the development of PSS innovation capability. Therefore, this research builds on and contributes to both the PSS literature and to the innovation literature.

Combining knowledge from PSS and capability literature with empirical findings from the case company resulted in a model which explains the development of PSS innovation capability. This is a research area which has attracted limited focus by researchers. Capability literature proposes how routines and activities are building blocks for capability development (Dosi, et al., 2000). The model presented in PAPER F shows how routines and activities in early phases of development could result in development of PSS innovation capability. Some of these routines, for example continuous customer interaction and promotion of cross-functionality, could naturally also be appropriate for product development. However, to build PSS innovation capability they are necessary. Another relevant contribution of this study is related with empirically examining the micro-foundations of capabilities or routines. Most prior studies take a company level view on capability development, without critically understanding of observing individual actions that drive routines and capability development. Therefore, combining knowledge of PSS and capability literature with empirical findings from the case company showed not only how PSS affects the organization but also how different types of PSS affect the organization in various degrees.

7.2 Implications for practice

7.2.1 Creating a PSS mindset

PSS is more than just hardware plus maintenance services. Paper E provides a figure of aerospace examples along the PSS continuum that shows the variety in PSS offers. This means that the increase of service offers is not limited to maintenance services, on the contrary these types of services could potentially decrease as PSS offers, such as monitoring systems or power by the hour, would increase. To communicate this variety of PSS offers would increase the awareness of the current PSS portfolio and thereby also inspire the creation of new PSS offers and create a PSS mindset within the organization.

A PSS mindset also means that the focus is on creating customer value, where the value is not only created through product functionality, but through the overall offer from the start of co-creation and collaboration to the end of the product life cycle. This also includes for example the partnership trust, optimal MRO services, product availability etc. Therefore, increased focus on customer value creation will support the creation of a PSS mindset.

7.2.2 Creating a PSS innovation climate

The focus on creating customer value rather than product functionality creates a larger solution space that is not limited to solutions related to the product. A larger solution space means more opportunities to create innovations. The focus on customer value is therefore needed to create a PSS innovation climate.

Having a creative workshop is a way to create an innovative climate. A creative and successful workshop is more than just the creation of post-it notes. In paper C is a description of a PSS innovation workshop that has tested creative methods/activities for PSS innovation. This workshop includes activities of visualising time perspective, identifying stakeholder/customer needs, and visualisation of hard and soft variables in prototypes which are important to create a PSS innovation climate. Such a workshop has also been facilitated at the company after this specifc study, where activities of goal formulation, scenario creation and roadmapping have been held with positive results regarding creating a common understanding of within the team and a common understanding of the time perspective. A PSS innovation climate is not only relevant during development phases but also in use phase, as well as for product/service upgrades.

Even though a workshop is a onetime occasion it creates an innovative foundation for the team. The results of the workshop can thereafter be developed further and the methods could also be supportive for individual creativity or to support communication after the workshop.

7.2.3 Creating a network for PSS innovation collaboration

There are seldom problems collaborating with people who are similar to ourselves (e.g. similar background, similar education etc), but when people from different companies, different educational backgrounds need to collaborate, such as needed in PSS development, collaboration challenges arises. Therefore, attention is needed for establishment of a common understanding. This research has shown the importance of a focus on customer value creation (a common goal for the

collaboration) and a focus on time perspective (a common view on the background, process and future of the collaboration). A long-term relationship with external partners creates stronger ties and better communication which supports the network for PSS innovation collaboration. A company therefore needs to highly value their collaboration networks, identify common goal of the collaboration and communicate the difference in time perspectives, to create strong ties and long-term relationships in the network for PSS innovation collaboration.

Internally there are also collaboration issues that can be handled through stronger ties and better communication. The further apart people are in the organization the more complicated the communication becomes. Gathering people within a team simplifies the communication and therefore also the collaboration. Having people with double competences also simplifies the communication between competence areas, since then there exists individuals who understand both sides. A company therefore needs to carefully select the competences for a PSS team and encourage job-rotation to create competence variation for PSS innovation and establish the internal network for the collaboration.

The product expertise plus PSS mindset at the case company has contributed to new PSS innovations on the military business side where the ties between product development and service development are strong. On the commercial side, the case company has experience in both product development and maintenance services but as a first-tier supplier, the ties between them are not as strong. Since information from the use phase is valuable in the early development phases of PSS, increased communication and stronger ties between service development and product development can lead to new PSS innovation opportunities even on the commercial business side.

Creating a PSS mindset within the organization supports the collaboration since it helps in the creation of a common understanding. If one thinks of products while the other thinks of services the communication is even more difficult than when both think in terms of PSS. The creation of a PSS mindset is therefore also important for the creation of a network for PSS innovation collaboration.

7.2.4 Creating PSS business models

The transition towards PSS innovation is more than just the creation of new business models, although this is of course part of it. One tool to use for designing PSS business models is 'The Business Model Canvas'. This is an appropriate tool since it focuses on value creation and customer relationships, however one needs to keep in mind to push for change during such activity so that not only the current business model emerges but also new opportunities. Further, it is important to add an activity of risk assessment since new business models involve new risks.

7.2.5 The importance of strategies

This research has shown the importance of strategy for the PSS transition and for the build-up of PSS innovation capability. The implementation of the 'soft product' strategy gave a PSS innovation boost at the case company. But the 'soft product' strategy was a Volvo strategy, and as the company became part of GKN, this strategy was lost. A question is how much of a PSS mindset that was lost with it, is unclear. Perhaps this strategy was most important to the initial software innovation (as

shown in this research) when the PSS innovation capability was built, but not as necessary now when new grounds have been broken. Perhaps something new, and potentially even better, could come in its place.

7.2.6 Building PSS innovation capability

It is probably possible to develop a PSS innovation without having appropriate capability, if one is lucky. To become a successful PSS innovation provider in the long run, one needs more than luck, the development of capability is needed. Capability is built up by routines and activities. Collaboration is the foundation and appropriate methodology helps in the creation of structure and to systematically address the issues and challenges. The routines to focus on to create PSS innovation capability are (as described in PAPER F): (1) Have continuous customer interaction, (2) Establish innovative PSS climate, (3) Promote cross-functionality, (4) Involve network partners, (5) Build PSS competence and (6) Establish PSS business. To establish these routines activities are needed on both organizational and team level. Further, the capability should be based upon the core capability of the company. To use the core competence of current offers to create new PSS innovation to minimize risks.

7.3 Reflections on quality assessment of conducted research

This section reflects upon the quality criteria presented in chapter 4.5 (Quality Assessment of Conducted Research) with the aim to enable review of quality of both research and report (thesis and papers).

7.3.1 Construct validity

Construct validity regards the development of appropriate measures for the concept that is being studied, which are related to the phase of data collection and composition (Yin, 2003). This research has followed the three tactics suggested by Yin (2003) for construct validity. (1) The use of multiple sources of evidence or data and methodological triangulation. Different data collection sources have been used, data has been collected at different times, space and persons. Interviewees for examples have been situated at different departments within the case company and had various positions at different levels to capture diverse views on the innovation process and to combine different perspectives. Different data collection methodologies have also been used: interviews, observations and workshops. (2) The establishment of a chain of evidence, the longitudinal aspects of this study and capturing the history of case company has capture the chain of events that has changed the company over time. (3) To have the draft report reviewed by key informants, interviewees and key people within the company have reviewed draft papers before publishing.

7.3.2 Internal validity – Trustworthiness

Internal validity regards the establishment of an underlying relationship, where certain conditions are shown to lead to other conditions, which are related to the data analysis phase (Yin, 2003).

Pattern matching analysis has been made using a spreadsheet with empirical data from transcribed interviews (further described in chapter 4.4.2) as suggested by Yin (2003) and Miles & Huberman (1994). Another example of a way that interpretations and inference of data has been minimized in

this research is the fact that all interviews have been conducted in Swedish. Because this has been the first language of both respondents and researcher, and the respondents have been more comfortable speaking in their first language. Translated quotes from interviews have often been used to illustrate how the narratives were constructed from the data.

Investigator triangulation have been used to some extent, analysis and results have been discussed in regular dialog with supervisors and involved researchers for a systematic comparison of different researchers' influences on the issue and the results.

Further, this research is not only based on PSS theory but also on other streams of literature in order to understand the complexity of the area. This is an example of Theory triangulation, the data has been analyzed using different theoretical perspectives, for example innovation management, resource based view or organizational theory to ensure different aspects on PSS innovation capability.

7.3.3 External validity – Generalizability and Transferability

External validity regards whether the research can be generalized and transferred to other settings (Herr & Anderson, 2005; Yin, 2003).

This research has been carried out in a company in the aerospace industry; hence the majority of the empirical findings originate from an aircraft engine component manufacturer. Some findings have also been gained from a company in the automotive industry in a cross-case study on creative workshop methods for PSS, which showed that although the industries are different, one B2B and one B2C, the challenges and needs of the PSS teams were similar.

Since the majority of the findings are based on one single company, its weakness may therefore be the limited generalizability. However, only because this study has largely been carried out at one single company at a particular time, with particular individuals, does not mean that the results can be made richly meaningful to people in other organizations (Checkland & Holwell, 1998). Although it is hard to claim generalizability of this research it is *transferable.* Transferability is dependent on similarities between contexts and is supported through thick descriptions (Lincoln & Guba, 1985).

In this research the closeness to the industry has enabled a rich picture of the situation, which has been captured and communicated through the use of real industrial examples and quotes in descriptions presented in articles and thesis. This research is therefore transferable to other industries, because readers can recognize similarities with situations of their own. The case company represents a large manufacturing industry, specifically those with high technology products, long product lifecycles, long development processes and focuses on safety concerns, characteristics similar to for example those in medical or automotive industries. The phenomenon of servitization is also widely found in other manufacturing industries. The challenges and the needs of the case company are not unique compared to other cases described in literature, and the methods that has been tested and analyzed are not aerospace specific. Therefore, the results (the methods, routines, activities) that are found to be supportive in this research could be transferred to other company with similar contexts/characteristics.

7.3.4 Reliability – Recoverability

Reliability in its traditional sense regards if a repeated study of the object would come to the exact same results and conclusion (Yin, 2003). In this study, as most other qualitative studies, the object (the company) undergoes continuous changes and it is therefore problematic to assess reliability in this traditional sense. During these years of study there have been reorganizations and individuals have changed positions. Therefore the question of reliability of this research rather has to do with *recoverability* (Checkland & Holwell, 1998), which means that anyone can trace the steps of the research and thereby understand how the findings were established.

To enable recoverability each study has had a clear purpose and included descriptions of how and why data were collected (Feldman, 2007). Recording, transcribing and documenting data, as well as comparing data in the spreadsheet for analysis and interpretations has also been central for assessing the reliability of the study (Flick, 2009). During the project regular dialog and discussion with involved researchers and supervisors has been performed to create relations between data collection and data analysis.

7.3.5 Verification

Verification of design methods tools can according to Blessing & Chakrabarti (2009) be achieved through application to practical design problems or according to Buur (1990) be achieved through acceptance by experienced designers.

The methods/tools suggested in this thesis have been tested in actual industrial cases, with teams working on PSS issues at present. The long innovation process has made it impossible to assess market success of tested methods in the duration of this research project. Instead the methods have been assessed according to the positive effects according to the participants. Further, research results and models have been discussed within the company which also is in line with *verification by acceptance* as defined by Buur (1990). The acceptance also means interaction with engineers over time, which has deepened the understanding. It has also influence their thoughts over time, but since this is an industrial PhD project with the objective of contributing to change, this has been a positive effect.

7.4 Suggestions for further research

This research project has focused on the aerospace industry, with one cross-case study in the automotive industry. Future research could extend the empirical base beyond the context of this research project to improve generalizability of the findings.

Although PSS is closely linked with sustainability aspects (because of the increased emphasis on the whole product life cycle), sustainability has not been in focus in this research project. Future research could have an increased emphasis on sustainability to see how the sustainability aspects affect the PSS capability at the company. Furthermore, methods and tools to support sustainable innovation would be of importance in the manufacturing industry in general and the aerospace industry specifically.

During these years of research the company has increased the focus on value driven development. However, the results from a questionnaire showed that there is a limited support system for this way of thinking and working. Further work to improve the support system for value driven development would potentially support the development of PSS innovation capability.

This research has exemplified how the supply chain position affects the capability of PSS development at the case company. Cases on first/second tier suppliers are rare in PSS literature; further research on this issue is therefore needed.

The Technology Readiness Level (TRL) is proposed (in PAPER B) to facilitate understanding for strategic collaboration between stakeholders. Although it is a tool that explains abstract maturity of new technologies, a similar tool to evaluate the maturity of PSS offers is not far off. Such a 'TRL for PSS' then needs to evaluate the maturity of the PSS offer depending on for example: (1) how well the customer value is defined and analysed, (2) how well the business case is defined, (3) the involvement of the customer and (4) how the process and support of the customer interaction is established within the organization. The TRL tool has shown to be useful in communication for innovation and a 'TRL for PSS' tool to evaluate the maturity of PSS offers could be helpful for a company in the PSS transition. Further work could include the development of such a tool. The research would then take a different view on capability than that presented in this thesis, but would build on the work by Tetlay (2011) on assessing capability readiness for PSS.

7.5 Concluding remarks

The transition towards becoming a PSS provider is challenging, therefore there is a need to build capability. For most manufacturing companies, the ways of working with developing and manufacturing products are mature and well established. Any change to existing processes is difficult, especially when many people across the organization need to be involved to make it happen. This thesis has focused on how to develop the collaboration for PSS, how to support the collaboration with methods and tools, and how to build the capability through routines and activities. The result show that the company has taken many steps in the creation of PSS innovation capability and in many ways they have managed it, but there are still further steps to be taken, implying continuous attention towards PSS innovation capability development.

Studying the development of PSS innovation, it has been evident that there are differences in time perspectives between people from different disciplines and that this challenges the vital collaboration between them. It has also been evident that the introduction of 'simple' tools that help the visualization of time can help the communication and collaboration for PSS innovation.

PSS refers to offers of integrated products and services. PSS therefore needs to be viewed as a whole concept, not as separate unites of products and services. Methodologies that help the development team think of the offer as a whole concept, support the development of PSS innovation. This research found that the methods and tools therefore need to focuses on value creation, take both hard and soft variables into account and be open to new possible business models. PSS innovation is

further supported by a PSS mindset that takes into account that PSS is more than just hardware plus maintenance services.

Interaction with customer is a means to create knowledge about the customer and the usage of the product, which of course is important for PSS development. Although this does not mean that one should do only what the customer says they want. This research has exemplified a disruptive PSS innovation where the customer was not aware of their need of a certain PSS solution. The customer interaction in this case created the knowledge that lead to a PSS offer that the customer did not know they wanted.

For long term PSS innovation, capability is needed. Capability is built by establishing routines and activities. The PSS transition means taking new business risk. These risks are minimized by using the core competence, which in the manufacturing organization is their product knowledge. This product competence exists and it is not easily copied, it is just a matter of using it in the right way. If combined with the knowledge about the usage phase, it creates the foundation for PSS innovation capability, which is a great foundation for new PSS innovation.

Hopefully, this thesis has provided some intriguing results that can inspire other researchers in the fields of PSS, innovation and capabilities. Further, based on the rich descriptions of challenges, methods and routines of a company in the aerospace industry that is building their PSS innovation capability, this research can also provide insights to practitioners in manufacturing industries in their aim to become PSS providers.

References

ACARE, 2010. *Beyond Vision 2020 (Towards 2050),* Brussels: Aeronautics and Air Transport - European Commission.

Aerospace Growth Partnership, H. G., 2013. *Lifting Off - Implementing the Strategic Vision for UK Aerospace,* London: Crown.

Allmendinger, G. & Lombreglia, R., 2005. Four Strategies for the Age of Smart Services. *Harvard Business Review,* Volume October, pp. 1-11.

Alonso-Rasgado, T., Thompson, G. & Elfström, B.-O., 2004. The Design of Functional (Total Care) Products. *Journal of Engineering Design,* 15(6), pp. 515-540.

Amabile, T., 1998. How to kill creativity. *Harvard Business Review,* 76(5), pp. 77-87.

Amit, R. & Schoemaker, P., 1993. Strategic Assets and Organizational Rent. *Strategic Management Journal,* Volume 14, pp. 33-46.

Anderson, H. & Lindström, G., 2008. Skapa kundnärvaro i innovationsprocessen. In: A. Olsson, ed. *Innovationsförmåga.* Stockholm: PIEp, Product Innovation Engineering program, pp. 40-58.

Anderson, J., Narus, J. & van Rossum, W., 2006. Customer Value Propositions in Business Markets. *Harvard Business Review,* Volume March, pp. 91-99.

Annique, C., 2007. Managing the Innovators for Exploration and Exploitation. *Journal of Technology Management & Innovation,* 2(3), pp. 4-20.

Assink, M., 2006. Inhibitors of disruptive innovation capability: a conceptual model. *European Journal of Innovation Management,* 9(2), pp. 215-233.

Aurich, J., Fuchs, C. & Wagenknecht, C., 2006. Life cycle oriented design of technical Product-Service Systems. *Journal of Cleaner Production,* Volume 14, pp. 1480-1494.

Baines, T. S., Lightfoot, H. W., Benedettini, O. & Kay, J. M., 2009. The Servitization of Manufacturing - A Review of Literature and Reflection on Future Challenges. *Journal of Manufacturing Technology Management,* 20(5), pp. 547-567.

Baines, T. S. et al., 2007. State-of-the-art in product-service systems. *Journal of Engineering Manufacture,* 221(Part B), pp. 1543-1552.

Barquet, A., Cunha, V., Oliveira, M. & Rozenfeld, H., 2011. *Business Model Elements for Product-Service System.* Braunschweigh, Germany, Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems.

REFERENCES

Benner, M. & Tushman, M., 2003. Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited. *Academy of Mangement Review,* 28(2), pp. 238-256.

Björklund, T., 2010. Enhancing creative knowledge-work: challenges and points of leverage. *International Journal of Managing Projects in Business,* 3(3), pp. 517-525.

Blessing, L. & Chakrabarti, A., 2009. *DRM, a Design Research Methodology.* Dordrecht Heidelberg London NewYork: Springer.

Brady, T., Davies, A. & Gann, D. M., 2005. Creating Value by Delivering Integrated Solutions. *International Journal of Project Management,* Volume 23, pp. 360-365.

Brezet, J., Bijma, A., Ehrenfeld, J. & Silvester, S., 2001. *The Design of Eco-Efficient Services,* Delft: Design for Sustainability Program, Delft University of Technology.

Brown, T., 2008. Design Thinking. *Harvard Business Review,* Volume June, pp. 84-92.

Burger, P. C. & Cann, C. W., 1995. Post-Purchase Strategy - A Key to Successful Industrial Marketing and Customer Satisfaction. *Industrial Marketing Management,* Volume 24, pp. 91-98.

Burt, R., 2000. The Network Entrepreneur. In: R. Swedberg, ed. *Entrepreneurship: The social science view.* Oxford: Oxford University Press, pp. 281-307.

Buur, J., 1990. *A Theoretical Approach to Mechatronics Design,* Lyngby, Denmark: PhD thesis, Institute for Engineering Design, Technical University of Denmark.

Börjesson, S. & Elmquist, M., 2011. Developing Innovation Capabilities: A Longitudinal Study of a Project at Volvo Cars. *Creativity and Innovation Management,* 20(3), pp. 171-184.

Cao, M. & Zhang, Q., 2010. Supply chain collaborative advantage: A firm's perspective. *International Journal of Production Economics,* Volume 128, pp. 358-367.

Checkland, P. & Holwell, S., 1998. Action Research: Its Nature and Validity. *Systematic Practice and Action Research,* 11(1), pp. 9-21.

Chesbrough, H., 2003. The Era of Open Innovation. *MIT Sloan Management Review,* Volume Spring, pp. 35-41.

Christensen, C., 2000. *The Innovators Dilemma.* New York: HarperBusiness.

Christensen, C. & Bower, J., 1996. Customer Power, Strategic Investment, and the Failure of Leading Firms. *Strategic Management Journal,* Volume 17, pp. 197-218.

Clayton, R., Backhouse, C. & Dani, S., 2012. Evaluating existing approaches to product-service system design: A comparison with industrial practice. *Journal of Manufacturing Technology Management,* 23(3), pp. 272-298.

REFERENCES

Cockayne, W., 2013. *Foresight & Innovation.* [Online]
Available at: http://foresight.stanford.edu/
[Accessed 27 05 2013].

Cohen, M. & Whang, S., 1997. Competing in Product and Service: A Product Life-Cycle Model. *Management Science,* 43(4), pp. 535-545.

Crossan, M. & Apaydin, M., 2010. A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature. *Journal of Management Studies,* 47(6), pp. 1154-1191.

Darroch, J. & McNaughton, R., 2002. Examining the link between knowledge management practices and types of innovation. *Journal of Intellectual Capital,* 3(3), pp. 210-222.

Davies, A., Brady, T. & Hobday, M., 2006. Charting a Path Toward Integrated Solutions. *MIT Sloan Management Review,* 47(3), pp. 37-48.

Day, G., 1994. The Capabilities of Market-Driven Organizations. *Journal of Marketing,* Volume 58, pp. 37-52.

Dewar, R. & Dutton, J., 1986. The Adoption of Radical and Incremental Innovations: An Empirical Analysis. *Management Science,* 32(11), pp. 1422-1433.

Dittrich, K., Duysters, G. & de Man, A.-P., 2007. Strategic repositioning by means of alliance networks: The case of IBM. *Research Policy,* Volume 36, pp. 1496-1511.

Dosi, G., Nelson, R. & Winter, S., 2000. *The Nature and Dynamics of Organizational Capabilities.* New York: Oxford University Press.

Dougherty, D., 2008. Bridging Social Constraint and Social Action to Design Organizations for Innovation. *Organization Studies,* 29(03), pp. 415-434.

Drucker, P., 1998. The Discipline of Innovation. *Harvard Business Review,* Volume November - December, pp. 3-8.

Easton, G., 2010. *One case study is enough,* Lancaster: LUMS.

Ehrenfeld, J., 2001. *Designing 'Sustainable' Product/Service Systems.* Tokyo, Presented at Ecodesign.

Eisenhardt, K. & Graebner, M., 2007. Theory Building From Cases: Opportunities and Challenges. *Academy of Management Journal,* 50(1), pp. 25-32.

Feldman, A., 2007. Validity and quality in action research. *Educational Action Research,* 15(1), pp. 21-32.

Flick, U., 2009. *An Introduction to Qualitative Research.* Fourth ed. Hamburg: Sage Publications.

REFERENCES

Francis, D. & Bessant, J., 2005. Targeting innovation and implications for capability development. *Technovation,* Volume 25, pp. 171-183.

Gill, K., 2002. Knowledge Networking in Cross-Cultural Settings. *AI & Society,* Volume 16, pp. 252-277.

Goldenberg, J., Horowitz, R., Levav, A. & Mazursky, D., 2003. Finding Your Innovation Sweet Spot. *Harvard Business Review,* Volume March, pp. 120-129.

Granovetter, M., 1973. The Strength of Weak Ties. *American Journal of Sociology,* 78(6), pp. 1360-1380.

Grant, R., 1991. The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review,* 33(3), pp. 114-135.

Griffiths-Hermans, J. & Grover, R., 2006. Setting the Stage for Creative New Products: Investigating the Idea Fruition Process. *Journal of the Academy of Marketing Science,* 34(1), pp. 27-39.

Gummesson, E., 2000. *Qualitative Methods in Mangement Research.* Second ed. California: Sage Publications.

Hamel, G., Doz, Y. L. & Prahalad, C. K., 1989. Collaborate with Your Competitors - and Win. *Harvard Business Review,* Volume January-February, pp. 133-139.

Hansén, S.-O. & Wakonen, J., 1997. Innovation, a winning solution?. *Internationa Journal of Technology Management,* 13(4), pp. 345-358.

Harrison, A., 2006. Design for service - Harmonising product design with a service strategy. *The ASME Turbo Expo, Barcelona,* Volume 2, pp. 135-143.

Hartman, J., 2004. *Vetenskapligt tänkande - från kunskapsteori till metodteori.* 2nd red. Lund: Studentlitteratur.

Helfat, C. & Peteraf, M., 2003. The Dynamic Resource-based View: Capability Lifecycles. *Strategic Management Journal,* Volume 24, pp. 997-1010.

Henderson, R. & Clark, K., 1990. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly,* Volume 35, pp. 9-30.

Henkel, J., 2006. Selective revealing in open innovation processes: The case of embedded Linux. *Research Policy,* Volume 35, pp. 953-969.

Herr, K. & Anderson, G., 2005. *The Action Research Dissertation.* California: Sage Publications.

Holland, S., Gaston, K. & Gomes, J., 2000. Critical success factors for cross-functional teamwork in new product development. *International Journal of Management Reviews,* 2(3), pp. 231-259.

REFERENCES

Howells, J., 1997. Rethinking the market - technology relationship for innovation. *Research Policy,* Volume 25, pp. 1209-1219.

Huston, L. & Sakkab, N., 2006. Connect and Develop: Inside Procter & Gamble's New Model for Innovation. *Harvard Business Review,* Volume March, pp. 58-66.

Håkansson, H. & Snehota, I., 1989. No Business is an Island: The Network Concept of Business Strategy. *Scandinavian Journal of Management,* 5(3), pp. 187-200.

IATA, 2013. *FACT SHEET: Fuel,* available at: http://www.iata.org/pressroom/facts_figures/fact_sheets/Pages/index.aspx: The International Air Transport Association (IATA).

Isaksson, O., Larsson, T. C. & Öhrwall Rönnbäck, A., 2009. Development of product-service systems: challenges and opportunities for the manufacturing firm. *Journal of Engineering Design,* 20(4), pp. 329-348.

Isaksson, O., Larsson, T. & Johansson, P., 2011. *Towards a Framework for Developing Product/Service Systems.* Braunschweig, Germany, Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems.

Jacoby, R. & Rodriguez, D., 2007. Innovtion, Growth, and Getting to Where You Want to Go. *Design Management Review,* 18(1), pp. 9-15.

Johnstone, S., Dainty, A. & Wilkinson, A., 2008. In serach of 'product-service': evidence from aerospace, construction, and engineering. *The Service Industries Journal,* 28(6), pp. 861-875.

Joore, P., 2008. The V-Cycle for system innovation translating a broad societal need into concrete product service solutions: the multifunctional centre Apeldoorn case. *Journal of Cleaner Production,* Volume 16, pp. 1153-1162.

Kelley, T., 2001. Prototyping is the shortland of innovation. *Design Management Journal,* Volume Summer, pp. 35-42.

Kihlander, I. et al., 2011. *Planning Industrial PhD Projects in Practice: Speaking Both 'Academia' and 'Practitionese'.* Technical University of Denmark, International Conference on Engineering Design, ICED11.

Kim, Y., Lee, S., Kim, J. & Do, S., 2012. *A Design Case of Product-Service Systems - Urban umbrella rental PSS.* Dubrovnik, Croatia, Proceedings of the 12th International Design Conference.

Kvale, S., 2009. *Den kvalitativa forskningsintervjun.* Lund: Studentlitteratur.

Laursen, K. & Foss, N., 2003. New human resource management practices, complementarities and the impact on innovation performance. *Cambridge Journal of Economics,* Volume 27, pp. 243-263.

REFERENCES

Lee, J. & AbuAli, M., 2011. Innovative Product Advanced Service Systems (I-PASS): methodology, tools, and applications for dominant service design. *International Journal of Advanced Manufacturing Technology,* Volume 52, pp. 1161-1173.

Leonard-Barton, D., 1992. Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Management Journal,* Volume 13, pp. 111-125.

Levitt, T., 1972. Production-line appraoch to service. *Harvard Business Review,* Volume September-October, pp. 41-52.

Lincoln, Y. & Guba, E., 1985. *Naturalistic Inquiry.* London: Sage.

Lockett, H., Johnson, M., Evans, S. & Bastl, M., 2011. Product Service Systems and supply network relationships: an exploratory case study. *Journal of Manufacturing Technology Management,* 22(3), pp. 293-313.

March, J., 1991. Exploration and Explotation in Organizational Learning. *Organization Science,* 2(1), pp. 71-87.

Martinez, V., Bastl, M., Kingston, J. & Evans, S., 2010. Challenges in transforming manufacturing organisations into product-service providers. *Journal of Manufacturing Technology Management,* 21(4), pp. 449-469.

Mathieu, V., 2001. Product services: from a service supporting the product to a service supporting the client. *Journal of Business & Industrial Marketing,* 16(1), pp. 39-58.

Mathieu, V., 2001. Service strategies within the manufacturing sector: benefits, costs and partnership. *International Journal of Service Industry Management,* 12(5), pp. 451-475.

Maurer, C. & Valkenburg, R., 2011. *Challenges in Networked Innovation.* Copenhagen, Denmark, 18th International Conference on Engineering Design (ICED).

McFadzean, E., 1999. Creativity in MS/OR: Choosing the Appropriate Technique. *Interfaces,* 29(5), pp. 110-122.

McFadzean, E. & Nelson, T., 1998. Facilitating problem-solving groups: a conceptual model. *Leadership & Organization Development Journal,* 19(1), pp. 6-13.

McLean, L., 2005. Organizational Culture's Influence on Creativity and Innovation: A Review of the Literature and Implications for Human Resource Development. *Advances in Developing Human Resources,* 7(2), pp. 226--246.

Meier, H., Völker, O. & Funke, B., 2011. Industrial Product-Service Systems (IPS2) - Paradigm shift by mutually determined products and services. *International Journal of Advanced Manufacturing Technology,* Volume 52, pp. 1175-1191.

Miles, M. & Huberman, A., 1994. *Qualitative Data Analysis.* 2nd ed. California: Sage Publications.

REFERENCES

Mo, J., 2012. Performance Assessment of Product Service System from System Architecture Perspective. *Advances in Decision Sciences,* Volume 2012, pp. 1-19.

Mont, O., 2002. Clarifying the concept of product-service system. *Journal of Cleaner Production,* Volume 10, pp. 237-245.

Morelli, N., 2002. Designing Product/Service Systems: A Methodological Exploration. *Design Issues,* 18(3), pp. 3-17.

Morelli, N., 2003. Product-service systems, a perspective shift for designers: A case study: the design of telecentre. *Design Studies,* 24(1), pp. 73-99.

Morelli, N., 2006. Devloping new product service system (PSS): methodologies and operational tools. *Journal of Cleaner Production,* Volume 14, pp. 1495-1501.

Mowery, D. & Rosenberg, N., 1979. The influence of market demand upon innovation: A critical review of some recent empirical studies. *Research Policy,* Volume 8, pp. 102-153.

Nahapiet, J. & Ghoshal, S., 1998. Social Capital, Intellectual Capital, and the Organizational Advantage. *Academy of Management Review,* 23(2), pp. 242-266.

Nonaka, I., 1994. A Dynamic Theory of Organizational Knowledge Creation. *Organization Science,* 5(1), pp. 14-37.

NRIA, F., 2013. *NRIA Flyg 2013 - Four steps for flying innovation - The Swedish Aerospace Research and Innovation Agenda,* Sweden: Föreningen Svenskt Flyg.

Olivia, R. & Kallenberg, R., 2003. Managing the transition from products to services. *International Journal of Service Industry Management,* 14(2), pp. 160-172.

O'Reilly, C. & Tushman, M., 2004. The Ambidextrous Organization. *Harvard Business Review,* Volume April, pp. 74-81.

Osterwalder, A. & Pigneur, Y., 2010. *Business Model Generation.* Lausanne, Switzerland: Self Published.

Patnaik, D. & Becker, R., 1999. Needfinding: The Why and How of Uncovering People's Needs. *Design Management Journal,* Volume Spring, pp. 37-43.

Pentland, B., Feldman, M., Becker, M. & Liu, P., 2012. Dynamics of Organizational Routines: A Generative Model. *Journal of Management Studies,* pp. 1-25.

Remneland-Wikhamn, B., 2011. Path dependence as barrier for 'soft' and 'open' innovation. *International Journal of Business Innovation and Research,* 5(6), pp. 714-730.

Roberts, E., 1988. Managing Invention and Innovation. *Research Technology Management,* 31(1), pp. 11-29.

REFERENCES

Romijn, H. & Albaladejo, M., 2002. Determinants of innovation capability in small electronics and software firms in southeast England. *Research Policy,* Volume 31, pp. 1053-1067.

Rothaermel, F. & Hess, A., 2007. Building Dynamic Capabilities: Innovation Driven by Individual-, Firm-, and Network-Level Effects. *Organization Science,* 18(6), pp. 898-921.

Salvato, C. & Rerup, C., 2011. Beyond Collective Entities: Multilevel Research on Organizational Routines and Capabilities. *Journal of Management,* 37(2), pp. 468-490.

Sammarra, A. & Biggiero, L., 2008. Heterogeneity and Specificity of Inter-Firm Knowledge Flows in Innovation Network. *Journal of Management Studies,* 45(4), pp. 800-829.

Schmidt, G. & Druehl, C., 2008. When Is a Disruptive Innovation Disruptive?. *The Journal of Product Innovation Management,* Volume 25, pp. 347-369.

Schramm, C., 2008. *Innovation Measurement - Tracking the State of Innovation in the American Economy,* s.l.: The Advisory Committee on Measuring Innovation in the 21st Century Economy.

Schreyögg, G. & Kliesch-Eberl, M., 2007. How dynamic can organizational capabilities be? Towards a dual-process model of capability dynamization. *Strategic Management Journal,* Volume 28, pp. 913-933.

Scott, W. & Davis, G., 2007. *Organizations and Organizing: Rational, Natural, and Open System Perspectives.* Pearson International Edition ed. New Jersey: Pearson Education.

Shneiderman, B., 2007. Creativity support tools: Accelerating Discovery and Innovation. *Communications of the ACM,* 50(12), pp. 20-32.

Sosa, M., Eppinger, S. & Rowles, C., 2007. Are Your Engineers Talking to One Another When They Should?. *Harvard Business Review,* Volume November, pp. 133-142.

Svengren Holm, L. & Anderson, H., 2008. Synkronisering mellan delprocesser ger ökad innovation. In: A. Olsson, ed. *Innovationsförmåga.* Stockholm: PIEp, Product Innovation Engineering program, pp. 60-77.

Tan, A. & McAloone, T., 2006. *Characteristics of Strategies in Product/Service-System Development.* Dubrovnik, International Design Conference.

Teece, D., Pisano, G. & Shuen, A., 1997. Dynamic Capabilities and Strategic Management. *Strategic Management Journal,* 18(7), pp. 509-533.

Tetlay, A., 2011. Capability readiness for product-service systems. *Journal of Engineering Manufacture,* 225(Part B), pp. 1471-1477.

Tukker, A. & Tischner, U., 2006. *New Business for Old Europe.* Sheffield, UK: Greenleaf Publishing.

REFERENCES

Tuppen, S., 2009. *Business Model Change Driven Technology Requirements, Manufuture Workshop,* Gothenburg: http://extra.ivf.se/manufuture2009/documentation/workshop/David_Williams_(S_Tuppen).pdf.

Uchihira, N. et al., 2008. Analysis and Design Methodology for Product-Based Services. *Lecture Notes in Computer Science,* Volume 4914, pp. 13-25.

Valkokari, K., Paasi, J. & Rantala, T., 2012. Managing knowledge within networked innovation. *Knowledge Management Reseach & Practice,* Volume 10, pp. 27-40.

Walter, M., 2009. *Social Research Methods.* 2nd ed. Australia: Oxford University Press.

Van de Ven, A., 1986. Central Problems in the Management of Innovation. *Management Science,* 32(5), pp. 590-607.

Vandermerwe, S. & Rada, J., 1988. Servitization of Business: Adding Value by Adding Services. *European Management Journal,* 6(4), pp. 314-324.

Wang, C. & Ahmed, P., 2007. Dynamic capabilities: A review and research agenda. *International Journal of Management Reviews,* 9(1), pp. 31-51.

Ward, Y. & Graves, A., 2007. Through-Life Management: The Provision of Total Customer Solutions in the Aerospace Industry. *International Journal of Services Technology and Management,* 8(6), pp. 455-477.

Vargo, S. L. & Lusch, R. F., 2008. From goods to service(s): Divergences and convergences of logics. *Industrial Marketing Management,* Volume 37, pp. 254-259.

Vargo, S. & Lusch, R., 2004. Evolving to a New Dominant Logic for Marketing. *Journal of Marketing,* Volume 68, pp. 1-17.

Vasantha, G. et al., 2013. A manufacturing framework for capability-based product-service system design. *Journal of Remanufacturing,* 3(8), pp. 1-32.

Williams, A., 2007. Product service system in the automobile industry: contribution to system innovation?. *Journal of Cleaner Production,* Volume 15, pp. 1093-1103.

Wise, R. & Baumgartner, P., 1999. Go Downstream - The New Profit Imperative in Manufacturing. *Harvard Business Review,* Volume September- October, pp. 133-141.

Yin, R., 2003. *Case Study Research: Design and Methods.* 3rd ed. Thousand Oaks, California: Sage Publications.