UNIVERSIDADE DE SÃO PAULO
ESCOLA DE ENGENHARIA DE SÃO CARLOS
DEPARTAMENTO DE ENGENHARIA DE PRODUÇÃO

MARINA DE PÁDUA PIERONI

Proposta de um Método para Desenvolvimento de uma Arquitetura de Processos de Negócio para apoiar a transição de empresas de manufatura para provedoras de Sistemas Produto-Serviço (PSS)

Proposal of a Business Process Architecture (BPA) Development Method for supporting the transition of manufacturing companies into Product-Service System (PSS) providers

São Carlos
2017

MARINA DE PÁDUA PIERONI

Proposta de um Método para Desenvolvimento de uma Arquitetura de Processos de Negócio para apoiar a transição de empresas de manufatura para provedoras de Sistemas Produto-Serviço (PSS)

Proposal of a Business Process Architecture (BPA) Development Method for supporting the transition of manufacturing companies into Product-Service System (PSS) providers

Dissertação apresentada à Escola de Engenharia de São Carlos da Universidade de São Paulo para obtenção do título de Mestre em Engenharia de Produção.

Área de Concentração: Gestão de Processos e Operações

Orientador: Prof. Dr. Henrique Rozenfeld

Dissertation presented to the Engineering School of São Carlos of the University of São Paulo as a requisite to obtain the title of Master of Science in Production Engineering.

Concentration Area: Processes and Operations Management

Supervisor: Prof. Dr. Henrique Rozenfeld

São Carlos

2017

Pieroni, Marina de Pádua
P615p Proposta de um Método para Desenvolvimento de uma Arquitetura de Processos de Negócio para apoiar a transição de empresas de manufatura para provedoras de Sistemas Produto-Serviço (PSS) / Marina de Pádua Pieroni; orientador Henrique Rozenfeld. São Carlos, 2017.

Dissertação (Mestrado) - Programa de Pós-Graduação em Engenharia de Produção e Área de Concentração em Processos e Gestão de Operações -- Escola de Engenharia de São Carlos da Universidade de São Paulo, 2017.

1. Sistemas produto-serviço. 2. Inovação de modelo de negócio. 3. Arquitetura de processos de negócio. 4. Modelo de referência de processos de negócio. I. Título.

FOLHA DE JULGAMENTO

Candidata: Bacharela **MARINA DE PÁDUA PIERONI.**

Título da dissertação: Proposta de um método para o desenvolvimento de uma arquitetura de processos de negócios para apoiar a transição de empresas de manufatura para provedoras de Sistemas Produto-Serviço (PSS)".

Data da defesa: 25/01/2017.

Comissão Julgadora: **Resultado:**

Prof. Titular **Henrique Rozenfeld**
(Orientador)
(Escola de Engenharia de São Carlos/EESC) aprovada

Profa. Associada **Silvia Inês Dallavalle de Pádua** aprovada
(Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto/FEARP-USP)

Prof. Dr. **Timothy Charles McAloone** aprovada
(Technical University of Denmark)

Coordenador do Programa de Pós-Graduação em Engenharia de Produção:
Prof. Associado **Aldo Roberto Ometto**

Presidente da Comissão de Pós-Graduação:
Prof. Associado **Luis Fernando Costa Alberto**

ACKNOWLEDGEMENTS

First of all, I would like to thank professor Henrique:Rozenfeld for the amazing supervision and the example of professional excellence in teaching and researching. I could not have achieved the same results of this study if it were not for his inspirational conduct, respect and especially his generosity in helping me during the learning process.

Moreover, I would like to thank Professor Silvia Inês Dallavalle de Pádua and Professor Tim McAloone for the discussions and suggestions given during my qualification exam, which contributed for improving the quality of this work.

Furthermore, I extend sincere thanks to the people directly and indirectly involved in this research. Primarily, I am very grateful to the company and professionals who authorized and participated in the application of the action research for developing the PSS BPA Development Method.

In addition, I would like to thank all colleagues and alumni from the Integrated Engineering Research Group, especially those who contributed directly or indirectly to the proposition of the PSS BPA Development Method. Ana Paula Barquet, Caio Marques, Carina Campese, Daniel Guzzo, Daniela Pigosso, Kênia Rodrigues, Maiara Rosa, Renato Carrião, Victor Macul, Professor Glauco Mendes, Professor Janaína Hornos da Costa Mascarenhas, and Professor Maicon Gouveia de Oliveira, thank you very much for making this study happen!

I am also very grateful to my parents, who gave me all support, stood by my side in all decisions, and made me feel beloved. Also, I am grateful to Vitor, not only for have encouraged me to pursue the master's program and being an example of determination, but mainly for his lightness, laughs and love that make life worth living.

Finally, I would like to acknowledge the financial support provided by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), for the masters scholarship, and by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo), for the *PSS Transition Framework* research project in which this study was comprised.

RESUMO

PIERONI, M. P. Proposta de um Método para Desenvolvimento de uma Arquitetura de Processos de Negócio para apoiar a transição de empresas de manufatura para provedoras de Sistemas Produto-Serviço (PSS). 2017. Dissertação (mestrado) – Escola de Engenharia de São Carlos, São Carlos, 2017.

Para se manterem competitivas e criarem valor para seus clientes, empresas de manufatura estão passando pelo processo da servitização, que é a transformação de suas ofertas baseadas em produtos físicos em soluções integradas de produtos e serviços, chamadas Sistemas Produto-Serviço (PSS). A servitização requer transformações nos modelos de negócio das empresas. Um dos principais desafios da servitização é redesenhar a dimensão de processos de negócio do modelo de negócios da empresa de maneira a operar as fases de meio de vida e final de vida de um PSS. Apesar de existirem casos de sucesso de PSS implementados há décadas, dificuldades operacionais ainda são citadas. Isto está associado com lacunas nas metodologias para desenvolvimento de modelos de negócio de PSS, as quais são focadas no desenvolvimento de novos PSS e carecem do nível de detalhes necessário para servitização. O objetivo desta pesquisa é propor um método para apoiar as empresas de manufatura no desenvolvimento da Arquitetura de Processos de Negócio do PSS durante a servitização, o que é base para o redesenho de processos destas organizações. Este método foi desenvolvido com o apoio da Metodologia de Pesquisa em Design, que contém quatro estágios. No primeiro e segundo estágios, uma revisão da literatura foi realizada para determinar os requisitos teóricos que guiaram a proposição do método. No terceiro estágio, a pesquisa ação foi utilizada para propor empiricamente o método. A pesquisa ação foi realizada em uma empresa multinacional do setor de saúde, que pretendia transformar um equipamento de diagnóstico por imagens em PSS orientado ao uso. No estágio final, o método passou por uma avaliação preliminar a fim de ser preparado para estudos de caso. Os resultados indicam que o método proposto tem potencial para apoiar as empresas na definição de arquiteturas de processos para PSS. Outras contribuições foram a proposição de um modelo de referência de processos para PSS baseado no Framework de Classificação de Processo e descobertas do caso real de servitização.

Palavras-chave: sistemas produto-serviço; inovação de modelo de negócio; arquitetura de processos de negócio; modelo de referência de processos de negócio.

x

ABSTRACT

PIERONI, M. P. Proposal of a Business Process Architecture (BPA) Development Method for supporting the transition of manufacturing companies into Product-Service System (PSS) providers. 2017. Dissertação (mestrado) – Escola de Engenharia de São Carlos, São Carlos, 2017.

In order to stay competitive and to create value to their clients, manufacturing companies are engaging in a process called servitization, which consists in transforming their existing physical product offerings into integrated bundles of products and services, called Product-Service Systems (PSS). Servitization compels manufacturing companies to change their business models. One of the main challenges of servitization is to redesign the business processes dimension of their business model in order to operate middle of life (MOL) and end of life (EOL) phases of PSS. Despite the existence of decades-long successful PSS cases, operational difficulties are still reported. This is associated to gaps in existing PSS business model design methodologies, which are focused on the development of new PSS and lack the required level of details for servitization. The goal of this study is to propose a method to support manufacturing companies during the servitization process in developing a PSS Business Process Architecture (PSS BPA), which is the basis for redesigning their business processes. The method was developed with the support of the Design Research Methodology (DRM), which comprises four research stages. In the first and second stages, a literature review was conducted to generate theoretical requirements for guiding the proposition of the PSS BPA Development Method. Action research approach was applied in the third stage to propose the PSS BPA Development Method empirically. Action research was carried in a large multinational manufacturing company from the healthcare sector, which intended to transform a diagnostic imaging product into a use-oriented PSS. In the last stage, the method received a preliminary assessment with the intent of being prepared for further applications in case studies. The results indicate that the PSS BPA Development Method has a potential for supporting companies in defining their PSS BPA. Other key contributions of the research were the proposition of a business process reference model for PSS based on the Process Classification Framework (PCF), and insights and findings obtained with the real case of servitization.

Key words: product-service system; business model innovation; business process architecture; business process reference model.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AD	UML 2.0 Activity Diagram
APQC	American and Productivity Quality Center
ARIS	Architecture of Integrated Information Systems
B2B	Business-to-Business
B2C	Business-to-Customer
BMC	Business Model Canvas
BOL	Beginning of life
BPA	Business Process Architecture
BPM	Business Process Management
BPML	Business process modeling languages
BPMN	Business Process Management Notation
CCOR	Customer-Chain Operations Reference-Model
CIMOSA	Computer Integrated Manufacturing Open System Architecture
CMMI AQC	Capability Maturity Model Integration for Acquisition
CMMI-DEV	Capability Maturity Model Integration for Development
CMMI-SVC	Capability Maturity Model Integration for Services
COBIT	Control Objectives for Information and Related Technology
CS	Comprehensive Study
CSF	Critical success factors
DFG	German Research Foundation
DRM	Design Research Methodology
DS	Descriptive Study
DT	Design Thinking
eTOM	Enhanced Telecom Operations Map
EI	Grupo de Engenharia Integrada (Integrated Engineering Group)

EOL	End of life
EPC	Event Driven Process Chain
ERP	Enterprise Resource Planning
FEI	Front-end of innovation
FFE	Fuzzy front-end
ICT	Information and Communication Technology
IDEF3	Integrated DEFinition Method 3
IoT	Internet of Things
IRM	Industrial Services Reference Model
IS	Initial Study
ITIL	Information Technology Infrastructure Library
Iwi	Institute for Information Systems
KPI	Key Performance Indicator
MOL	Middle of life
PCF	Process Classification Framework
PS	Prescriptive Study
PSS	Product-Service System
PSS BPA	Product-Service System Business Process Architecture
RAD	Role Activity Diagram
RBS	Review-based Study
RC	Research Clarification
SCOR	Supply Chain Operations Reference-Model
SLA	Service Level Agreement
SML	Strategy Modeling Language
VAC	Value-added chain
VCA	Value Creation Architecture

VCH	Value Creation Hierarchy
VRM	Value Reference Model
XPDL	XML Process Definition Language
Y-CIM	Y (-shaped)-Computer Integrated Manufacturing

TABLE OF CONTENTS

1 Introduction

This chapter is organized in four sections. The first section (section 1.1) aims to introduce the main themes covered in this research and to justify this work in the literature context. The second section (section 1.2) defines the research's question and objective. The third section (section 1.3) delimits the scope of the research by underlining what is and what is not included in it. Finally, the fourth section (section 1.4) presents the structure of this document to support the reader in understanding this work.

1.1 Context and justification

The increasing competitiveness of global markets along with more complex customers' needs and greater demand for environmental responsibility have compelled manufacturing companies, that generally focus on designing and commercializing physical products as their core business, to innovate in different aspects in order to sustain their competitive advantage (GEBAUER; BRAVO-SANCHEZ; FLEISCH, 2007, p. 12; TAN et al., 2009, p. 1). Innovation is sometimes misinterpreted by only approaching product and technology aspects (GARCIA; CALANTONE, 2002, p. 112). According to the Oslo Manual, innovation is multifaceted as it may comprise novelties or significant improvements that a firm promotes in four aspects: processes, products, marketing or organizational arrangement (OECD, 2005, p. 47). In accordance to that, Keeley et al. (2013) go further in suggesting the existence of ten types of innovation distributed in three categories, as depicted in Table 1. According to these authors, combining different types of innovation is the key for reinventing a business in a protective way, since it burdens or postpones the replication of a company's strategy (KEELEY et al., 2013, p. 16).

In this sense, Product-Service System (PSS) is currently an appealing approach to support manufacturing companies' innovation process. The economic concept of PSS is not novelty (BOEHM; THOMAS, 2013, p. 245; GOEDKOOP et al., 1999, p. 20; MONT, 2004, p. 19). Some companies, such as Rolls Royce, have implemented and evolved this strategy for more than two decades (SMITH, 2013, p. 16). However, developing a PSS for the first time is considered an innovation from the provider's perspective, as it implies in a new interpretation of the notion of a product (BAINES et al., 2007; GEBAUER; BRAVO-SANCHEZ; FLEISCH, 2007; OLIVA; KALLENBERG, 2003). Moreover, offering a PSS involves different types of innovation (as presented

in the third column of Table 1) at the same time. This may increase the probability of shielding the company's business strategy against competitors, as suggested by Keeley et al. (2013, p.16).

Table 1 - Ten types of innovation

Category of Innovation	Focus	Types of Innovation
Configuration	Innovation related to internal aspects of a company	• Profit model • Network • Structure • Processes
Offering	Innovation related to the core offer of a company	• Product performance • Product system
Experience	Innovation that are more perceivable to customers	• Service • Channel • Brand • Customer engagement

SOURCE: adapted from Keeley et al. (2013)

Providing a PSS requires a shift from selling pure physical products towards selling an integrated package of products and services (BOEHM; THOMAS, 2013, p. 252). Manufacturing companies intending to become PSS providers need to transform their business models by adding value to their offerings (formerly involving only pure physical products) through services in order to satisfy new necessities of customers, which are more concerned with obtaining results than with consuming or owning physical goods. This transformational process performed by companies when they move from manufacturing providers to PSS providers is usually referred to as servitization (BAINES et al., 2009a, p. 555).

The redesign or definition of a new business model is essential for servitization (LINDAHL; RÖNNBÄCK; SAKAO, 2009, p. 165; MARTINEZ et al., 2010, p. 460; NEELY, 2009, p. 105; REINARTZ; ULAGA, 2007; TUKKER; TISCHNER, 2006, p. 1555; ULAGA; KONDIS; MCTEAGUE, 2013, p. 1). However, this shift is challenging for companies once it impacts several business elements such as cultural orientation, strategic choices, financial structure, operations, and relationships with partners and customers (BAINES et al., 2009a, p. 555; GEBAUER; BRAVO-SANCHEZ; FLEISCH, 2007, p. 20; OLIVA; KALLENBERG, 2003, p. 161). To overcome those issues, methods for designing business models are usually applied in the Front-End of

Innovation (FEI)[1]. This results in simplified representations of business' dimensions[2] with insufficient level of details for the PSS context, specially concerning the description of the company's internal value chain organization and how this is related to strategy (BARQUET et al., 2013, p. 149; TAN, 2010, p. 63). Hence, a PSS business model may have its design started in the FEI, but it should be further detailed during the development phase, concurrently to the complete design of the new PSS.

Although many specific methods were developed to design new PSS business models (not in the scope of servitization), how to cope with the transformational aspects of servitization requires further investigation, since cases of PSS implementation still report problems, such as operational hurdles and financial uncertainties (BAINES et al., 2009a; CAVALIERI; PEZZOTTA, 2012; CLAYTON; BACKHOUSE; DANI, 2012; TUKKER, 2015; VASANTHA et al., 2012). Therefore, there is still need for complete approaches oriented to servitization that are able to support the PSS transition from conception to implementation.

Vis-à-vis this background, Pieroni et al. (2016) developed the *PSS Transition Framework*, which is a result of a research project of the EI (Engenharia Integrada) Research Group in which the author is member. The *PSS Transition Framework* is a comprehensive and iterative approach to support servitization. Since servitization is the process of transforming a product oriented manufacturer into a PSS provider, as already mentioned, Figure 1 presents the PSS Life Cycle Management process to locate the servitization approach.

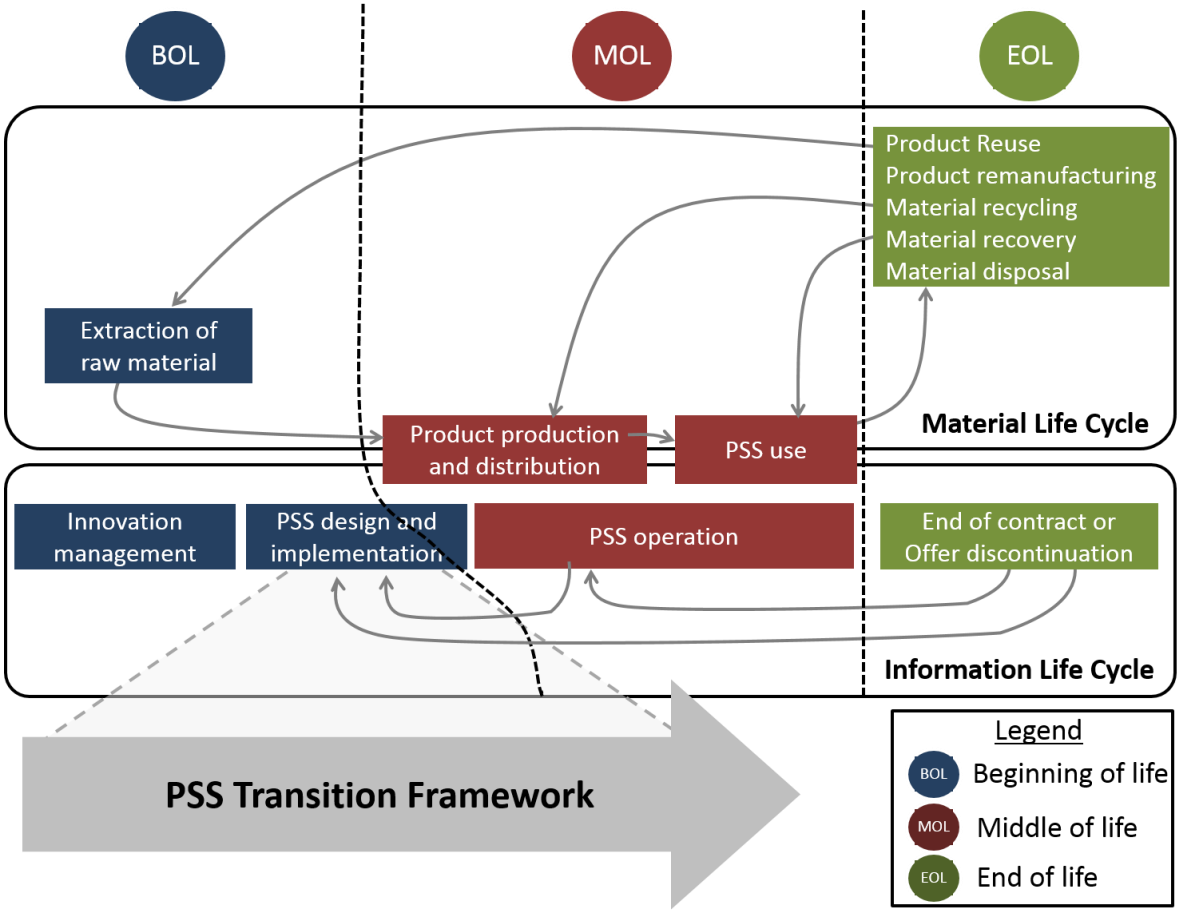
PSS Life Cycle has two perspectives: the information and the material life cycle. The information life cycle deals with the information management perspective, i.e. with the acquisition, creation, storage control, update, disposal, archive of information in whole PSS life cycle. Before the material life cycle even begins, the first phases of the information life cycle are "innovation management" and "PSS design and implementation". "Innovation management" deals with the ideation and portfolio

[1] The Front End of Innovation (FEI), also known as Fuzzy Front End (FFE) or up-front, covers the predevelopment activities of product or service innovation process. It encompasses the generation and selection of new ideas, the definition of the product or service concept, and the preliminary evaluation of the concept for approving or terminating the product or service development project (COOPER, 1988, p. 243).

[2] The business dimensions considered here are adapted from Osterwalder and Pigneur (2010, p. 15) and encompass: customer segments, value proposition, channels, customer relationship, key processes, key resources, key partnerships, costs and revenues. For more details, consult section 3.1.4.

management of new development projects. When a specific project is defined in the pipeline, this PSS offer is designed and implemented. The material life cycle occurs after a PSS has been developed and released and runs until the end of life of each PSS.

Figure 1 - PSS Life Cycle Management



SOURCE: created by the author.

The information life cycle phase “PSS operation” is concurrent to the “product production and distribution”, and the “use phase”, which occur during the middle of life (MOL) [3]. The production pulls the extraction of raw material defined in the product specification. Therefore, the information and material life cycle in the beginning of life (BOL) [4] are timely separated. The information BOL for a specific PSS takes place once and the material BOL continuously happens during the offering of this PSS. At the end

[3] The middle of life (MOL) comprises the usage and maintenance of the PSS (CAVALIERI; PEZZOTTA, 2012, p. 280). It is “characterized by the Sell, Contract, Use and Assist phases of the PSS” (PEZZOTTA; CAVALIERI; GAIARDELLI, 2012, p.222).
[4] The beginning of life (BOL) comprises design and implementation phases of the PSS (CAVALIERI; PEZZOTTA, 2012, p. 223; PEZZOTTA; CAVALIERI; GAIARDELLI, 2012, p. 280).

of a use phase in one customer the material end of life (EOL) [5] is carried out, which runs in parallel to the end of contract of the information EOL. This phase is recurrent and the product element of the PSS can undergo to the EOL strategies listed in the figure. However, there is other information EOL phase, when the organization decides to stop offering the current PSS.

Since the *PSS Transition Framework* deals with the transformation of the business based on an already existing offering, it should be applied during the "design and implementation" phases of the PSS Life Cycle Management process, as illustrated in Figure 1. Afterwards it might be possible that the organization become competent in developing PSS. In that case, the previous described BOL information life cycle turns to be the business as usual. This evaluation of this competence is out of the scope of this research. The focus is on the servitization.

Thus, the *PSS Transition Framework* has a life cycle perspective, describing main deliverables for the servitization process during the BOL, in order to enable the MOL and EOL phases of a PSS, as illustrated in Figure 2. The white circles in the figure represent the expected deliverables or group of information along the life cycle (MOL, BOL and EOL). The big blue arrow represents the information flow from MOL and EOL that feedbacks the BOL phase, after the PSS is launched.

The focus and differential of the *PSS Transition Framework* is on the BOL phase, where it considers that a "complete PSS business model" encompasses different levels of detailing of business' dimensions (see the white bordered box in Figure 2). This deliverable is named "complete business model" to differentiate from the common understanding of a business model, which is "a simplified and aggregated representation of the relevant activities of a company" (WIRTZ et al., 2015, p. 41). This common understanding is considered as the "initial PSS business model" in this study. The development of the "complete PSS business model" requires simultaneously combining interconnected[6] methods from different disciplines[7] to develop each

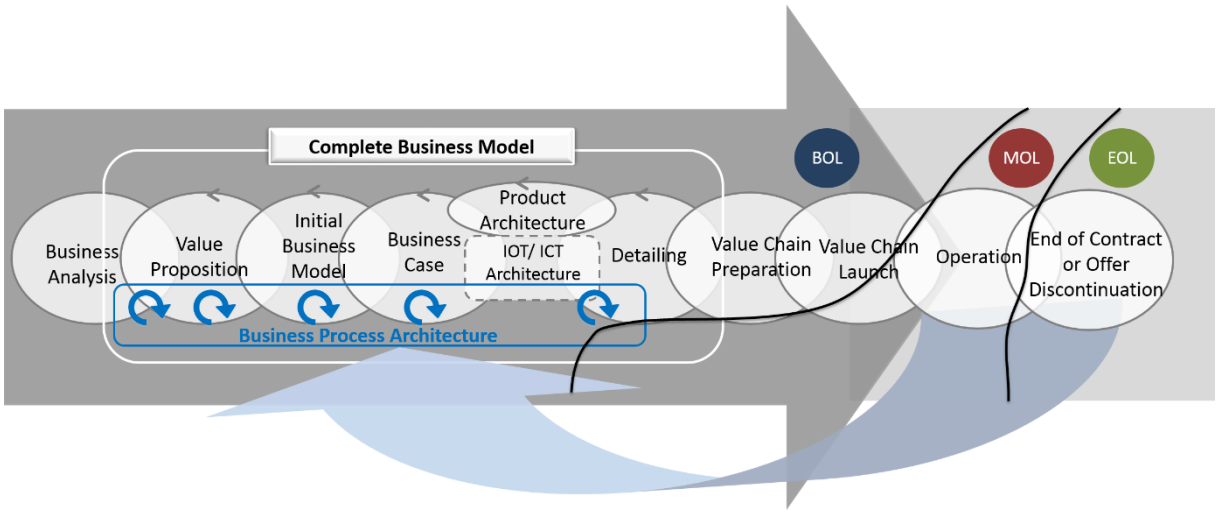
[5] The end of life (EOL) phase encompasses processes related to the PSS dismissal and product disposal (CAVALIERI; PEZZOTTA, 2012, p. 222; PEZZOTTA; CAVALIERI; GAIARDELLI, 2012, p. 280).

[6] The interconnection means that some activities of different methods are executed concurrently and anticipated in a way that the application of a specific method already defines variables of subsequent methods as illustrated by the superposition of the deliverables in Figure 2.

[7] Disciplines are areas or fields of study, for example, Information Systems, Business Management, Engineering, and Design.

dimension, or deliverable, instead of applying individual methods usually presented in literature, which are only able to deliver the aggregated and simplified view of the business model at a high level of abstraction.

Figure 2 - PSS Transition Framework



SOURCE: adapted from Pieroni et al. (2016).

One of the deliverables of the *PSS Transition Framework* is the Business Process Architecture (BPA) (see the blue-bordered box in Figure 2). The BPA represents the company's systematic arrangement of business processes at a tactical level in order to achieve its goals (HARMON, 2015, p. 55). PSS operation compels manufacturing companies to change their business processes (DAHMANI; BOUCHER; PEILLON, 2013, p. 35) by creating new core[8] processes to encompass customers' and stakeholders' requirements, and remodeling (which may include adapting or excluding unnecessary processes) existing core and back-office[9] processes to support the provision of new services and optimize profitability (REINARTZ; ULAGA, 2007, p. 2; ULAGA; KONDIS; MCTEAGUE, 2013, p. 2). Since not only a single process but a collection of end-to-end business processes should be assessed and transformed during the servitization, methods for developing a BPA are an appealing approach to start defining the business processes for the operation of a PSS during MOL and EOL phases (SABBAGH; DIJKMAN; WESKE, 2012, p. 65).

[8] Core processes "create value for external customers and so are essential to the business" (VOM BROCKE; ROSEMANN, 2015, p. 11).
[9] Back-office processes encompass administrative activities that do not require direct contact with customers and support the provision of services inside a company. Such processes are usually led by the Accounting, Human Resources and IT departments, for example (METTERS; VARGAS, 2000, p. 663; VOM BROCKE; ROSEMANN, 2015, p. 58).

Defining a BPA demands the specification of the collection of business processes of a company as well as the interrelationship between those processes, the interface of those processes with strategy, the enabling resources (such as IT systems) for each process, the responsible people or organizational element for each process, and a set of key performance indicators (AREDES; PÁDUA, 2014, p. 246). Since elements such as strategy, processes, resources and partnerships are related to or comprised in the business model of a PSS, then this research adopts the approach of applying a BPA method integrated within the complete business model definition for a PSS. This method for developing the BPA intends to detail the business model's dimensions "key processes"[10], "key partnerships" and "key resources" required for PSS operation during MOL and EOL phases.

PSS literature does not explicitly mention Business Process Architecture when introducing how to define the business processes for the PSS operation. Some methods for designing PSS sparsely apply concepts from BPA. There are, however, methods for BPA definition developed in Business Process Management (BPM) discipline. Nevertheless, they are not oriented to the PSS transformation's context.

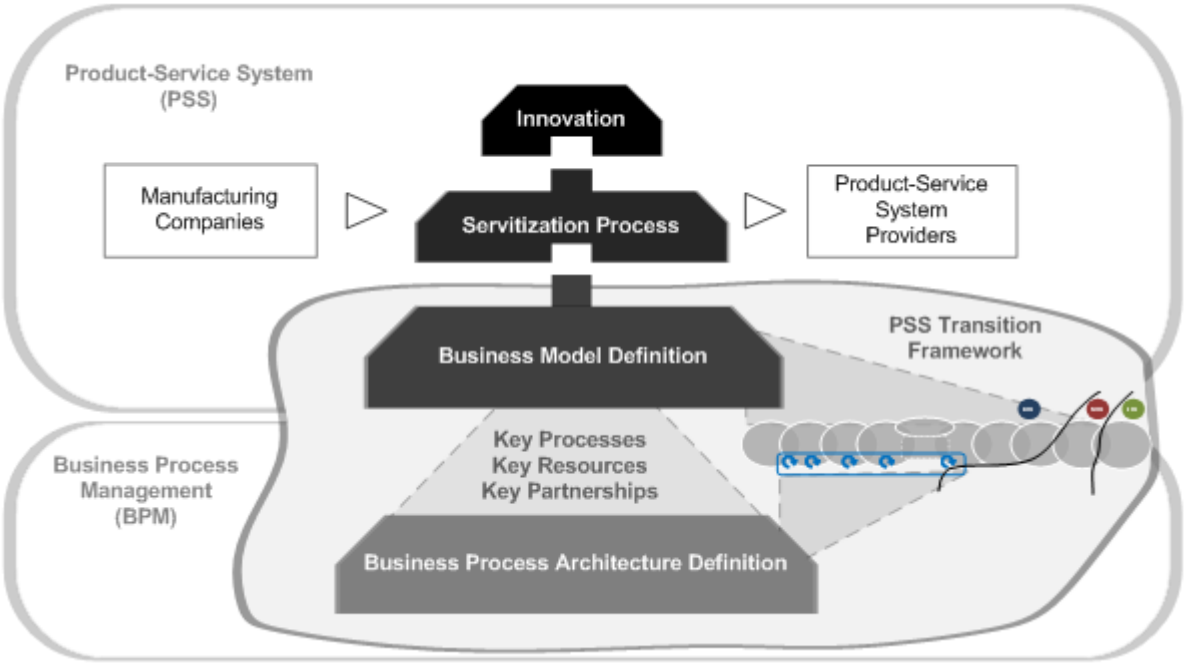
Since Qu et al. (2016, p. 12) suggest that methods from other areas should be adapted to the PSS context in order to cope with the servitization challenges previously presented in this chapter, then there is a justification for applying existing methods from BPM discipline integrated with the servitization process for developing the Business Process Architecture for the operation of a PSS in MOL and EOL phases.

Summing up, the current research was developed in parallel with the PSS Transition Framework (PIERONI et al., 2016). It focuses on proposing one of the methods that support the application of the PSS Transition Framework. This method aims at developing a BPA for the operation of the PSS during MOL and EOL phases. Nevertheless, as illustrated in the bordered blue box of Figure 2, this method for developing the BPA should be applied during the beginning of life (BOL) of the PSS, in a way of planning and preparing what the PSS will experience in its future life cycle phases (MOL and EOL) after its implementation (PEZZOTTA; CAVALIERI; GAIARDELLI, 2012, p. 222).

[10] The Business Model Canvas (OSTERWALDER; PIGNEUR, 2010, p. 36) applies the term "Key Activities", instead of Key Processes. This last term was one of the adaptations of this work.

Figure 3 summarizes the context and justification of this research described in this section 1.1.

Figure 3 - Context and justification of the research



SOURCE: created by the author.

1.2 Research question and objective

Based on the research justification identified in section 1.1, this study aims to answer the question: How should existing methods from BPM field for defining BPA be applied during the servitization process to support manufacturing companies in defining their business processes for the operation (MOL and EOL phases) of a PSS?

Hence, the objective of this study is to propose a method, called PSS BPA Development Method, to define the Business Process Architecture (BPA) for operating the MOL and EOL phases of Product-Service Systems along with and connected to the Complete Business Model's development (BOL phase) for the servitization of manufacturing companies.

1.3 Research scope

This section aims to delimit the scope of the research by stating, "what is" and "what is not" part of it, as described in Table 2.

Table 2 - Scope of the research

What is the research's scope	What is not the research's scope
The proposal and discussion of one method to be applied in the servitization process: • This method, called PSS BPA Development Method, is applied during the BOL phase of the *PSS Transition Framework* and generates only one deliverable of the complete servitization process, which is the Business Process Architecture (BPA). • The BPA generated by this method encompasses the set of business processes required for enabling the operation of a PSS during the MOL and EOL phases.	The proposal and discussion of all methods involved in the servitization process: • This research does not intend to discuss the complete design process model applied for guiding the servitization process during the BOL phase (which is the *PSS Transition Framework*). • Defining or discussing the methods applied to obtain other deliverables of the *PSS Transition Framework* (such as the Design Thinking applied for obtaining the Value Proposition, the Financial Analysis Tool applied for obtaining the Business Case) besides the Business Process Architecture or those intrinsically related to it.
The PSS BPA Development Method's application covers: • The development phase of a PSS (BOL): occurring in parallel with the definition of Value Proposition, Business Model, Business Case and part of the Detailing (with process modelling until "activity[1] level"), as illustrated in Figure 2. • A case of use-oriented PSS. • The studied company, which was a multinational large-sized business, adopted the strategy of launching the PSS without opening a subsidiary. As they already had mature core (such as product manufacturing and development) and support processes (such as IT and HR management), the focus was on detailing the necessary processes related to the services' offer. • The transformation of existing products in PSS offers: as described in the previous line, the product is already developed and commercialized by the studied company, but it demands some adaptations to incorporate requirements for being used in PSS context. • The identification of main required changes in existing Product and Information and Communications Technologies (ICT) Architectures.	The PSS BPA Development Method's application does not cover: • The implementation phase of the PSS (BOL): complete Detailing (with process modelling until "task[2] level"), Value Chain Preparation, and Launching, as illustrated in Figure 2. • The Operation (MOL) and End of Contract (EOL) phases of the PSS, as illustrated in Figure 2. • Cases of product-oriented PSS or result-oriented PSS. • The development of completely new PSS offers or companies. • The development of new Product and Information and Communications Technologies (ICT) Architectures.

[1] Activities are groups of actions necessary to deliver a definable part of product or service. In modeling notations, it is possible to depict the interrelationships and business rules at the "activity level", however without operational details. For more details, consult section 3.2.1.

[2] Tasks are the detailed steps required for performing a piece of work or an activity (CBOK, 2013, p. 442). They represent the operational action, and are commonly referenced as job instructions in modeling notations. For more details, consult section 3.2.1.

SOURCE: created by the author.

1.4 Document structure

This document is structured in five chapters, as depicted in Figure 4.

Chapter 1 introduces the content of this work by presenting the context and justification (section 1.1), the research question and objective (section 1.2), the research's scope (section 1.3), and the document structure (section 1.4).

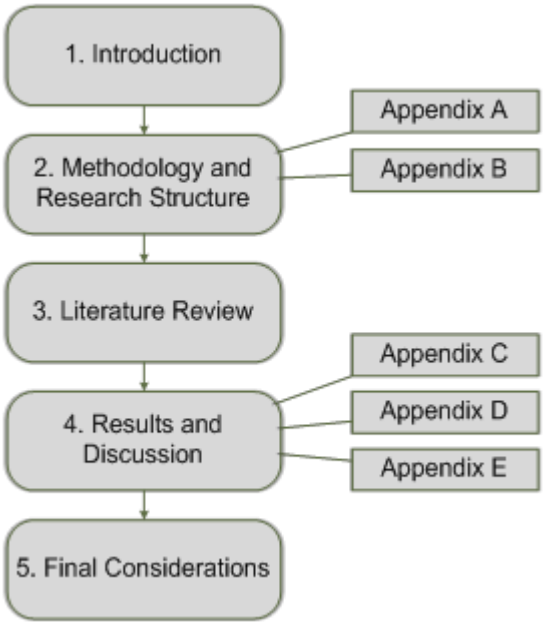
Chapter 2 describes the methodology applied in this research. It is divided in two sections that encompass the methodological approach (section 2.1) and the stages in which the research was structured (section 2.2).

Chapter 3 contains a non-exhaustive literature review of the main themes approached by this work, including the following sections: Product-Service Systems and Servitization (section 3.1), and Business Process Architecture (section 3.2). At the end of this chapter, the literature review is synthetized (section 3.3).

Chapter 4 presents the results of this research and discusses them in light of the theoretical background. It is organized in seven sections that encompasses: the description of the Context and Purpose of the action research applied for proposing the PSS BPA Development Method (section 4.1), the description of the three action research cycles (sections 4.2, 4.3, and 4.4), a synthesis of the proposed PSS BPA Development Method (section 4.5), and a preliminary assessment of the PSS BPA Development Method (section 4.6).

Finally, chapter 5 closes this document with a discussion about the application of action research in this study and recommendations for future PSS researches (section 5.1), reflections about the servitization process obtained with the empirical application (section 5.2), conclusions of this research (section 5.3), and limitations and future research opportunities (section 5.4).

Figure 4 - Document structure



SOURCE: created by the author.

2 Methodology and research structure

The objective of this chapter is to describe the methodology by which this research was conducted. It is organized in two sections: section 2.1 gives an overview of the general methodological approach, while section 2.2 describes the research structure specifying methods and tools applied in each stage.

2.1 Methodological approach

The methodological framework adopted in this research is the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti (2009).

The DRM is a scientific approach that indicates a “set of methods and guidelines to be used as a framework” for planning and implementing design researches (BLESSING; CHAKRABARTI, 2009, p. 9). It is important to highlight that DRM is not a method for designing, but a method for researching in the design field. One advantage of DRM is its iterative nature, which enables certain flexibility in the application of the methods. Moreover, it stimulates the use of empirical data as a means of understanding and getting closer to practical reality, which increases the probability of producing results that can be used in practice.

Design research involves a “process of identifying a need in the design field and developing a solution for it” (BLESSING; CHAKRABARTI, 2009, p. 12). Based on that information, the objective of the present study can be interpreted as a design research, since defining a business process architecture method for supporting the design of PSS operational processes (for MOL and EOL phases) is a solution for an organizational need or problem inside the servitization context. Furthermore, this solution is developed to be applied and support the BOL phase of the PSS (more specifically the Design phase), as already explained in sections 1.1, 1.2, and 1.3. Therefore, the DRM is a suitable approach to support this research. Additionally, the flexibility and empirical applicability of DRM allow an in depth analysis of the Product-Service System Business Process Architecture (PSS BPA) creation combining scientific and organizational knowledge, which is missing in current PSS theoretical background.

The DRM framework comprehends four stages (BLESSING; CHAKRABARTI, 2009, p. 15):

- Research Clarification (RC): This stage guides the researcher in investigating suggestions and facts that can support the definition of a research goal. Based on the discoveries, current and future desired scenarios of the studied situation are described at high-level.
- Descriptive Study I (DS-I): This stage supports the researcher in understanding the existing situation scenario in deeper details. The idea is to focus on influencing factors that will guide the proposition of the future solution[11].
- Prescriptive Study (PS): With a greater understanding of the current scenario and its influencing factors, researchers are able to propose a systematic solution and more comprehensive description for the desired scenario. The elaboration of this solution may be cyclical and revisit previous stages. Determining if the proposed solution is in agreement with the desired one requires an assessment step, which is approached in the following stage.
- Descriptive Study II (DS-II): DS II aims to evaluate if the proposed solution matches with the desired scenario in order to determine if the final solution was identified or, in negative cases, to take a decision of proceeding with further iterations for improving the desired solution. The evaluation of the solution in this stage may comprise aspects such as its applicability, usability and success.

DRM stages are iterative and can occur in parallel, although usually they are depicted in linear sequence for didactic purpose. Hence, the research can be initiated in any of the stages and only some of the four stages may be applied depending on each research type or instantiation of the methodology. Likewise, the level of details, content, and methods applied in each stage varies according to the research's circumstance (BLESSING; CHAKRABARTI, 2009, p. 17).

According to Blessing and Chakrabarti (2009, p. 18) there are seven main research types, as described in Table 3. They are based on whether the state-of-the-art with

[11] Blessing and Chakrabarti (2009, p. 4) use the term "support" to describe a spectrum of "strategies, methodologies, procedures, methods, techniques, software tools, guidelines and information sources" that can be applied to improve design. In this study the word "support" was substituted by the term "solution", which fits better the intended objective of this work.

respect to a particular stage is obtained with a review-based study or a comprehensive study followed by an initial study. A review-based study (RBS) is grounded purely on literature review. A comprehensive study (CS) may comprise literature review, empirical study, and development or assessment of a solution by the researcher. Finally, an initial study (IS) concludes the study by introducing a set of analysis and discoveries about the results and preparing them for being applied in further researches.

This research fits the type 3, which is oriented to the development of new solutions (BLESSING; CHAKRABARTI, 2009, p. 61). The solution in the case of this research is the PSS BPA Development Method. In order to select this approach, after evaluating the research's objective against research types (column 1 in Table 3), an analysis about each research stage was conducted to confirm that the classification was correct (columns 2, 3, 4 and 5 in Table 3).

Table 3 - Main research types in DRM framework

Research Type	**Approach in DRM Research Stages**			
	Research Clarification (RC)	Descriptive Study I (DS-I)	Prescriptive Study (PS)	Descriptive Study II (DS-II)
1. Comprehensive study into criteria	RBS →	CS		
2. Comprehensive study of existing solution	RBS →	CS →	IS	
3. Development of new solution	RBS →	RBS →	CS →	IS
4. Comprehensive evaluation	RBS →	RBS →	RBS → IS/CS	CS
5. Development of new solution based on comprehensive study of existing solution	RBS →	CS →	CS →	IS
6. Development of new solution and comprehensive evaluation	RBS →	RBS →	CS →	CS
7. Complete project	RBS →	CS →	CS →	CS

SOURCE: adapted from Blessing and Chakrabarti (2009).
NOTE: RBS: review-based study; CS: comprehensive study; IS: initial study.

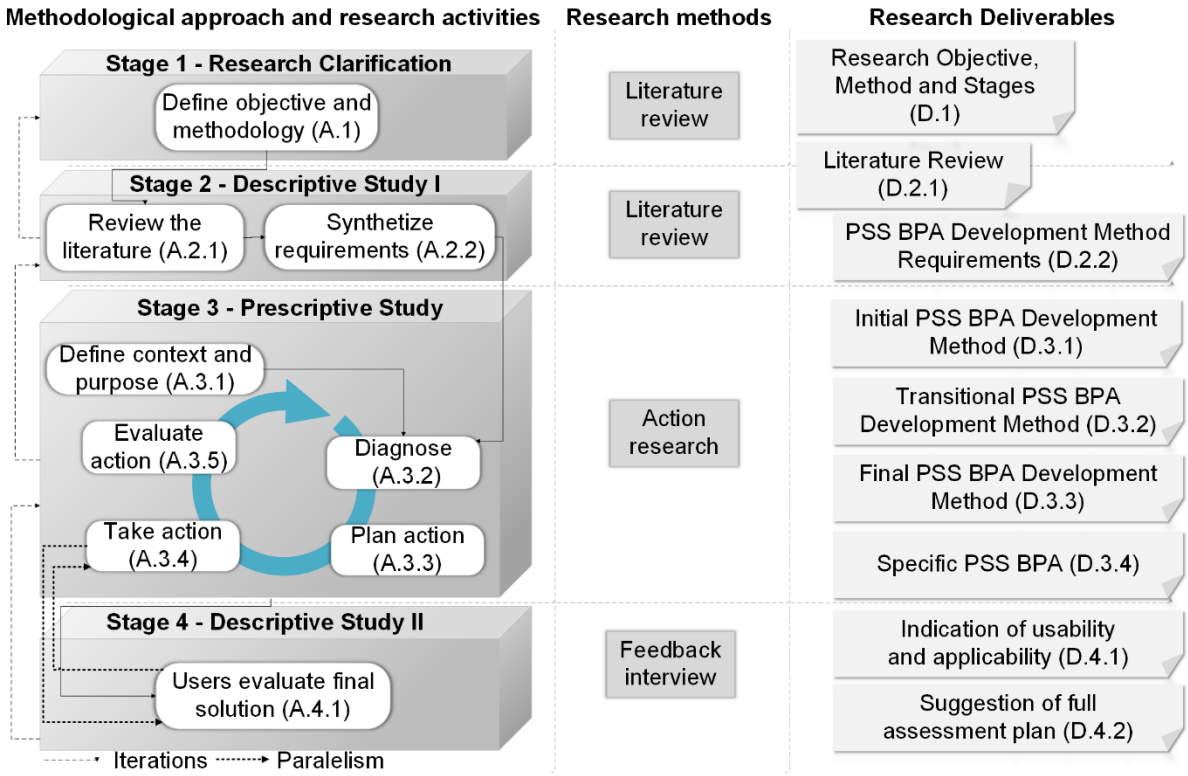
In all seven situations, Research Clarification stage is based on literature review, so the same procedure was adopted in this work. As already described in section 1.1, PSS literature indicates that existing solutions for PSS business process architecture design are not comprehensive and lack the appropriate level of details for the servitization scenario. Therefore, based on literature review it is only possible to develop a preliminary plan of the PSS BPA Development Method containing possible deliverables and activities that must be refined in practice. According to Blessing and Chakrabarti (2009, p. 61), a review-based Descriptive Study I and a comprehensive Prescriptive Study should be undertaken in such cases. The complete PSS BPA Development Method is developed in the Prescriptive Study. Finally, a Descriptive Study II may be necessary to conclude the study by showing the main findings and consequences of results and preparing them for next researches, which is achieved with an Initial Descriptive Study II. In this study, an Initial Descriptive Study II is necessary to highlight insights and questionings that should be investigated in future researches in order to verify the usability and success of the PSS BPA Development Method in other case studies, which will enable generalizations to be made.

Therefore, the DRM framework adopted in this research comprises: Research Clarification and Descriptive Study I stages based on literature review, Prescriptive Study based in comprehensive study with the support of action research method, and finally a Descriptive Study II based on initial study also with the support of action research and non-directive interviews, as presented in Figure 5.

The stages Prescriptive Study and Descriptive Study II are partly performed in parallel, because the evaluation of the application of the BPA Development Method that is supposed to occur during DS II is already accomplished during the action research cycles in the PS. In fact, according to Blessing and Chakrabarti (2009, p. 193), in terms of DRM, the action research corresponds to a cyclic process involving Prescriptive Study and Descriptive Study II, after a Descriptive Study I.

Besides the action research applied during the Prescriptive Study, other auxiliary methods are applied to support each stage of this research, as illustrated in Figure 5. These methods and activities comprised in each stage are thoroughly presented in the next section.

Figure 5 - Methodological approach of the research



SOURCE: created by the author.

2.2 Research structure

2.2.1 Research Clarification (RC)

The purpose of Research Clarification is to define the research problem. The main activity of this stage is *Define objective and methodology (A.1)*. It comprises tasks such as defining the research objective (section 1.2), selecting the methodological approach and research tools, and defining the research stages (chapter 2).

Research Clarification stage is review-based, therefore, activity A.1 is executed by means of an initial literature review, which encompasses the main topics of this research: product-service systems and servitization, and business process architecture.

This stage generates the first deliverable *Research objective, method and stages (D.1)* and partially contributes to the *Literature Review (D.2.1)* that is presented in chapter 3.

2.2.2 Descriptive Study I (DS-I)

Descriptive Study I is review-based and aims to consolidate the theoretical background of the research in order to enable the proposition of the PSS BPA Development

Method. It consists of two activities designated as *Review the literature (A.2.1), and Synthetize literature for PSS BPA Development Method requirements (A.2.2).*

Descriptive study I contributes to this work with two deliverables:

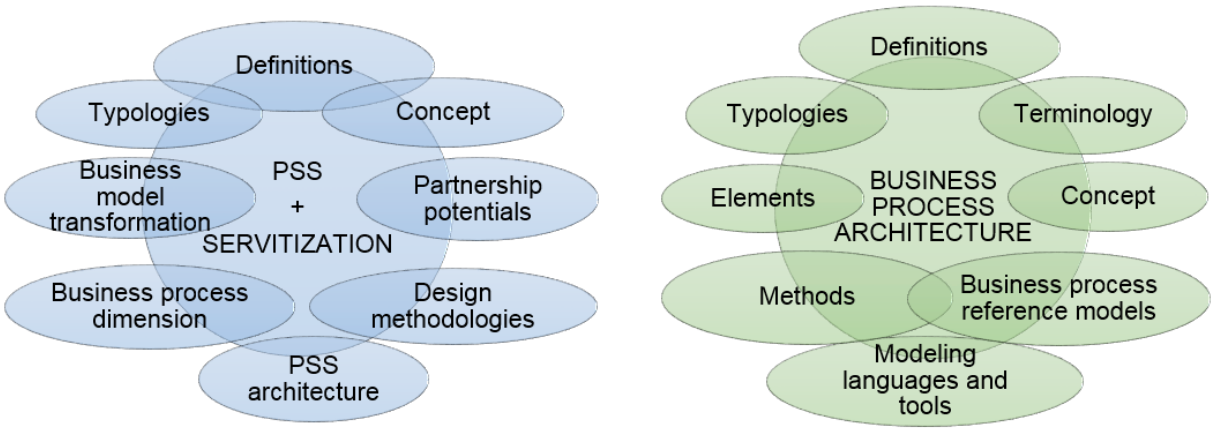
- *(D.2.1) Literature Review* (presented in chapter 3),
- *(D.2.2) PSS BPA Development Method Requirements* (presented in section 3.3).

Each activity of Descriptive Study I is supported by specific methods and tools as described in the following sections.

2.2.2.1 (A.2.1) Review the literature

A literature review is performed once it is a suitable method to acquire knowledge about specific themes. This activity's objective is to gain deeper understanding on the main topics briefly explored during Research Clarification: (I) product-service systems and servitization, and (II) business process architecture.

Figure 6 - Literature review topics



SOURCE: created by the author.

As depicted in Figure 6, the first topic explores ideas such as PSS and servitization definitions, concept and typologies, business model transformation, partnership network potentials for PSS, design methodologies for PSS, PSS architecture, and business process dimension in PSS (including topics such as the impacts of servitization in business process dimension and the connection between service architecture, capabilities and the business process dimension in PSS). The second topic comprises notions of BPM terminology, BPA definition and typologies, BPA

methods, BPA elements, and process modeling foundations, which include business process reference models, modeling languages, and modeling tools.

This literature review is performed with the support of the databases *Google Scholar, Scopus* and *Web of Science*. Although the absence of scientific rigor of *Google Scholar* is questioned by some academics, according to Falagas et al. (FALAGAS et al., 2008, p. 339), this database is the most expansive in retrieving information. Therefore, it is used in this research as a means of identifying and refining the main Key Words, authors and journals for subsequent search in *Scopus* and *Web of Science*. After selecting the main key-words in *Google Scholar*, the search proceeds within Scopus, which achieves a wider range of journals (FALAGAS et al., 2008, p. 339). Then a final search is conducted in the *Web of Science* to retrieve articles published before 1995, which is a limitation of *Scopus* database (FALAGAS et al., 2008, p. 342).

During the search for the topic Business Process Architecture, it was identified that BPA literature is not so concentrated in scientific papers and journals as the PSS literature. BPA topic appears in only few selected journals, being the majority of publications found in books from *Springer Link* publisher, in Industry Associations, or in open sources on internet. As this study intends to follow scientific rigor, this last source was not considered. Therefore, searches by recurrent authors, specific journals and mainly publisher *Springer Link* were considered for BPA topic.

Regarding the selection of papers, for the PSS topic, the most cited papers are chosen. Their title, abstract, and conclusions are read. After this first filter, the researcher proceeds by reading the results of the relevant papers, and if they are relevant, then the entire paper is considered for reading. For BPA topic, existing papers and book chapters from *Springer Link* publisher are retrieved from *Scopus, Web of Scien*ce or main specific journals. After this, the same procedure and filters from the PSS topic are applied. Furthermore, Industry Associations or Normative Organizations' websites are consulted for the recurrently cited Business Process Reference Models in scientific papers or *Springer Link* books.

This activity completes the deliverable *Literature Review (D.2.1) that is presented* in chapter 3.

2.2.2.2 (A.2.2) Synthetize literature for PSS BPA Development Method requirements

This activity's objective is to identify potential requirements for guiding the development of the PSS BPA Development Method during the Prescriptive Study. This occurs by synthetizing the outcomes of literature review previously performed in the Descriptive Study I in order to highlight insights that can answer the main research question.

The deliverable of this activity is *PSS BPA Development Method Requirements (D.2.2)*, which is presented in section 3.3.

2.2.3 Prescriptive Study (PS)

The purpose of this stage is to create the PSS BPA Development Method. Prescriptive Study is based on a comprehensive study conducted by means of action research. The following subtopics explain in detail what is the action research approach as well as relevant aspects for its application.

2.2.3.1 What is action research?

Action research is a systematic and inquiring approach that combines scientific methods with organizational knowledge, and involves the active collaboration of researchers and companies' members to propose solutions to real organizational problems while building theory in practice.

It consists of "an approach for introducing and evaluating change" (BLESSING; CHAKRABARTI, 2009, p. 40) that was originally applied in organizations and programs, but has increased its presence in the design field. According to Blessing and Chakrabarti (BLESSING; CHAKRABARTI, 2009, p. 41), there is an overlap between DRM and action research, and many of the methods from action research could also be applied in DRM.

As already indicated in section 2.1, action research in terms of DRM, corresponds to a cyclic process involving Prescriptive Study and Descriptive Study II, after a Descriptive Study I. The main difference between action research and DRM is their aim regarding the evaluation of the solution. While action research focus on individualization of a solution, DRM aims at generalization. As a consequence, action research applies on-site evaluation of the developed solution, which involves many short-cycles to gradually improve the local solution, while DRM evaluates the solution in a realistic but

not necessarily in the real situation, which involves fewer and longer cycles that may be carried off-site (BLESSING; CHAKRABARTI, 2009, p. 193).

The main distinctions of action research when compared to Case Studies – the most applied approach in PSS empirical research - are: (i) the theory is built (COUGHLAN; COGHLAN, 2002, p. 222) or refined concurrently with action (BASKERVILLE, 1999, p. 18); (ii) it is performed collaboratively between practitioners and researchers, and therefore the researchers have an active role in the solution execution; (iii) it simultaneously intervenes and contributes to solving practical problems and updating theory; and (iv) it is mainly focused on understanding the change in complex social systems (BASKERVILLE, 1999, p. 7; COUGHLAN; COGHLAN, 2002, p. 222).

Although action research does not require a complete previous theoretic method in order to solve the scientific problem (COUGHLAN; COGHLAN, 2002, 2009), some authors suggest and apply this technique for testing and refining existing theoretical frameworks[12] in practice (BASKERVILLE, 1999, p. 13; NEELY et al., 2000, p. 1131; PUHAKAINEN; SIPONEN, 2010, p. 763). For instance, Baskerville (1999, p. 18) highlights that the existence of a theoretical framework is a premise for the action to be considered research and not consultancy.

Originated in the Social Sciences field, action research has been recognized as an appropriate research method in different fields such as Medical Sciences (BASKERVILLE, 1999, p. 2), Education, Organization Development (BASKERVILLE; MYERS, 2004, p. 329), Information Systems (BASKERVILLE, 1999, p. 2; BASKERVILLE; MYERS, 2004, p. 329; PUHAKAINEN; SIPONEN, 2010), and Operations Management (COUGHLAN; COGHLAN, 2002, 2009; NEELY et al., 2000).

In the Operations Management research field, which is the scope of this study, the laboratories are the “alive” organizations. Therefore, it is important to encompass both the practitioners and researchers interests while performing a research. In view of that, action research is suitable, because it conciliates satisfying the practical requirements of managers while contributing to theory (GILL; JOHNSON, 2002, p. 94). Furthermore, action research enables observing and understanding behaviors associated to complex human systems embedded in an organization as they suffer transitions (COUGHLAN; COGHLAN, 2002, p. 225).

[12] Theoretical frameworks are the theoretical foundations that guide the action cycles for proposing a solution.

2.2.3.2 Why is action research applied in this study?

Action research was selected in this study, for four main reasons:

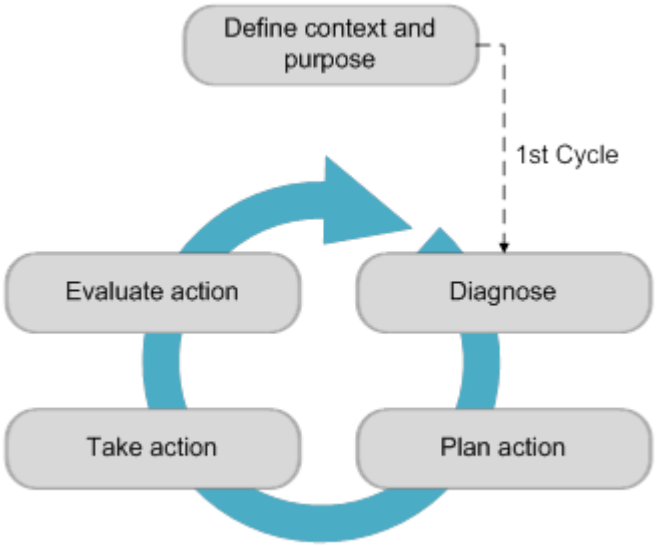
1. The first reason lies on the belief that complex social processes involving human interactions should not be reduced for analysis, as they can only be studied as whole entities. The best way to conduct research in such scenarios is by introducing changes in these systems and observing how they react, which can be accomplished through action research (BASKERVILLE, 1999, p. 4; COUGHLAN; COGHLAN, 2002, p. 225). As described in section 1.1, PSS transformation (or servitization) involves many challenges related to cultural and organizational changes, and so it can be considered a complex social process. Therefore, action research seems to be an appropriate research method for this study.
2. The second reason concerns the fact that the empirical application allows an in depth and holistic understanding (BASKERVILLE, 1999, p. 5; COUGHLAN; COGHLAN, 2002, p. 225) of PSS BPA development, which is fundamental for the context in which a consensual theoretical ground is not yet stablished.
3. The third reason is based on the arguments of Blessing and Chakrabarti (2009, p. 41) that identify the overlap between DRM and action research, and suggest the application of action research's methods in DRM. As already mentioned in the first aforementioned reason, the servitization context involves changes in organizational and cultural aspects, which varies depending on each organization's reality. Due to that, the author of this study understands that DRM, which is not necessarily evaluated in the real situation, is not enough to propose a solution in the servitization context. Hence, action Research has a potential to complement DRM with methods that enable the application and evaluation of the solution in the real situation, adjusting to each organizational setting.
4. Finally, as already explained in this section, action research applies for refining theoretical frameworks in practice, which is the case of this study.

Furthermore, since most of PSS publications are based on case studies, adopting action research is another contribution of this research to the PSS field.

2.2.3.3 How to perform action research?

There are many types and approaches for conducting an action research (BASKERVILLE, 1999, p. 9; GILL; JOHNSON, 2002, p. 87). This work adopts the action research method proposed by Coughlan and Coghlan (2009), which is specific for the Operations Management field. It consists of an initial activity “define context and purpose” followed by a cyclical process that encompasses “diagnose”, “plan action”, “take action”, and “evaluate action” activities (Figure 7). After each evaluation, a new cycle may be restarted if necessary.

Figure 7 - Action research method



SOURCE: adapted from Coughlan and Coghlan (2009).

The Prescriptive Stage of DRM comprises the same activities of an action research cycle as proposed by Coughlan and Coghlan (2009). They are explained in details in the following sections.

The main deliverables of Prescriptive Study are *Initial PSS BPA Development Method (D.3.1)*, *Transitional PSS BPA Development Method (D.3.2)* and the *Final PSS BPA Development Method (D.3.3)*, both representing the evolutionary versions of the PSS BPA Development Method. Additionally, as in action research the PSS BPA Development Method is proposed while being applied in a real company, consequentially this stage also delivers the *Specific PSS BPA (D.3.4)* for the company involved in the action research. Results of this stage are presented in Chapter 4.

2.2.3.3.1 (A.3.1) Define context and purpose

The objective of this activity is to determine the context of the research project. This consists of understanding the motivations for executing the action, from the perspectives of the organization and the research (COUGHLAN; COGHLAN, 2009, p. 247).

Regarding the organization's side, it is important to investigate political, economic, social and technical forces that drive the necessity for action. Additionally, it is the moment for the researchers to establish the collaborative partnerships with the organization's stakeholders involved in the project (COUGHLAN; COGHLAN, 2009, p. 248).

From a research's perspective, it is worth exploring the value and benefits of studying the action as well as justifying why using action research method and what are the expected results and contributions to science (COUGHLAN; COGHLAN, 2009, p. 248).

The first task of this activity aims to determine the organization's intention for action. As suggested in literature (BASKERVILLE, 1999, p. 19; COUGHLAN; COGHLAN, 2002, p. 225), action research enables the application of qualitative or quantitative tools from traditional research. Therefore, this task is performed by means of qualitative and non-directive interviews with key stakeholders inside the company. A semi-structured interview script (Appendix A) with main topics related to the objective of this task - represented by the underlined text previously presented in this section - supports the researcher with a guide for conducting the interviews. The intention of these interviews is to understand the "real world" of the organization through capturing trends and contextual aspects. Therefore, an interview protocol with generic topics is applied instead of an interview questionnaire in order to promote open discussion and avoid restricting or influencing the interviewees' answers with directed enquiring and closed structured answers (YIN, 2011, p. 135).

Collected data from the interviews are registered in a personal research notebook[13]. Then data are compiled, categorized in labels according to this activity's objectives (underlined text in previous paragraphs), and analyzed in order to produce a description of the organization's context and intentions towards action.

[13] "Personal research notebook" is the instrument used by the researcher to register data from interviews and observations. Alternative terms with the same meaning also encountered in literature are "personal journal" or "personal diary" (COUGHLAN; COGHLAN, 2009; YIN, 2011).

The second task of this activity consists of reviewing the research's purpose defined during the Research Clarification (section 2.2.1) in order to guarantee that its objectives are being considered in the action research.

The outcome of this activity is presented in section 4.1.

2.2.3.3.2 (A.3.2) Diagnose

This activity consists of identifying problems and diagnosing the current scenario of the company's business process architecture before planning and taking action (COUGHLAN; COGHLAN, 2009, p. 249).

"Diagnose" is performed by triangulation of different qualitative methods as suggested by Yin (YIN, 2011, p. 147). This involves combining methods such as qualitative interviews with main stakeholders of the organization involved in the project; observations during meetings, lunch and coffee breaks; and review of documents. Observation may seem a trivial method and too much dependent on the observer's perspective, however if properly performed (consult section 2.2.3.4), it is essential to capture concealed or sensitive elements associated to human relationships and behaviors, that cannot be transmitted with only analyzing what they explicitly report, and this is fundamental for action research (BASKERVILLE, 1999; COUGHLAN; COGHLAN, 2009, p. 240; YIN, 2011).

As this study is inserted in the scope of the *PSS Transition Framework* research (as explained in section 1.1), the interviews are supported by semi-structured questionnaires with open questions that are based on the Business Model Canvas' forces as predicted by the *PSS Transition Framework* (PIERONI et al., 2016, p. 414). Different versions of the questionnaire are applied depending on the stakeholder's functional role (Appendix B) in order to contextualize and individualize the interviews.

Collected data from interviews, observations, or document review are also registered in a personal research notebook. Additionally, copies of the original collected documents are kept with the researcher. Then, data are compiled through selecting interesting expressions, observations, and text that were related specifically to "operational processes" or "quality of service provision problems". Selected terms are synthetized to exclude duplicates and organized in problem categories, determined by

the application of a “cause and effect diagram”[14] adapted from Goldratts’ Theory of Constraints (TAYLOR III; MURPHY; PRICE, 2006, p. 653). Finally, based on this analysis, the researcher is able to take the conclusion about the context by answering the underlined question previously stated in this section.

The company’s project leader actively participates during this activity, by attending the interviews, facilitating the contact with the organization’s stakeholders, and validating the results. According to Coughlan and Coghlan (2009, p. 250), this cooperation is fundamental in action research as a means to ensure that the tacit and technical knowledge associated with cultural and intrinsic aspects of each organization are considered in the solution.

The outcomes of this activity are described in detail in section 4.2.1.

2.2.3.3.3 (A.3.3) Plan action

The objective of this activity is to plan the execution of the action research in order to develop the BPA for operating the PSS.

Plan action involves, between other activities, preparing the necessary theoretical framework and tools for supporting the action research. As already mentioned, since literature is sparse in providing a method for defining the business process architecture for operating the PSS in MOL and EOL phases, then it is not possible to obtain a complete solution able to be tested through case studies in this stage. Instead, a preliminary outline containing the main potential elements (deliverables and activities) of the PSS BPA Development Method is suggested based on the *PSS BPA Development Method Requirements (D.2.2)* previously defined, as explained in section 2.2.2.2.

In the first cycle of the action research, the activity “plan action” generates the deliverable *Initial PSS BPA Development Method (D.3.1)*, which consists of an initial version of the method containing potential deliverables and activities to be refined and

[14] Goldratts’ Theory of Constraints states that a certain group of processes have a constraint (weakest link) that controls the production rate of the entire system. Based on that, he developed a thinking process comprising a sequence of steps for locating the constraint (“What to change?”), defining a solution for it (“What to change to?”) and the way to implement it (“How to make the change?”). In order to determine “What to change”, he developed a tool called Current Reality Tree (CRT), which involves practice and logical based common sense for determining the root cause of a problem. The CRT consists of a diagram that shows the cause and effect relationships of undesired effects (symptoms) with the core problem (TAYLOR III; MURPHY; PRICE, 2006, p. 653).

improved during the first action research cycle. In addition, some tools for supporting the application of the method are described, as presented in section 4.2.2.1. Additionally, a project plan describing the cycles of the action research and the key stakeholders participating in the activities of each cycle need to be identified during the first cycle and updated in each of the following cycles, as described in sections 4.2.2.2, 4.3.1, and 4.4.1.

As indicated by Coughlan and Coghlan (2009, p. 251), this is also the moment for ensuring engagement and commitment from the company's management and main stakeholders involved in the project. Therefore, the company's leader participates in the definition of the project's plan, which is also validated with the management board. The project's leader works as a facilitator and is responsible to communicate the plan to the selected stakeholders and ensure their participation in the activities.

2.2.3.3.4 (A.3.4) Take action

The purpose of this activity is to execute the action plan of the action research (COUGHLAN; COGHLAN, 2009, p. 251), which is conducted by means of structured workshops and work meetings. Collected data during these workshops and meetings, consisting of the results of methods, insights, observations, lessons learned, and further questioning, are recorded in a personal research notebook.

After the end of each action research cycle, this activity generates potential solutions for the research problem. However, the solutions may not be definitive, since the subsequent activity (section 2.2.3.3.5) involves assessing the outcomes of the solution for further improvement. Therefore, *Take Action (A.3.4)* results in *Transitional BPA Development Method (D.3.2),* which represent another deliverable of this work. Results of this activity are described in sections 4.2.3, 4.3.2, and 4.4.2.

2.2.3.3.5 (A.3.5) Evaluate action

"Evaluate action" involves evaluating the outcomes of the performed action (as described in section 2.2.3.3.4) for completeness and consistency. The evaluation at the end of each action research cycle aims at individualization of the results. In other words, it aims at improving the initial PSS BPA Development Method and the PSS BPA proposed, regarding the context of a specific organization, for further testing the improved PSS BPA Development Method in the same organization in additional cycles of action research.

The collected data registered in personal research notebooks or recorded as feedbacks from the company's collaborators with their permission at the end of each meeting are analyzed in order to conclude if the original diagnosis was correct (consistency assessment), and if the action was correct (consistency assessment) and applied in appropriate manner fulfilling the initial requirements (completeness assessment) (COUGHLAN; COGHLAN, 2009, p. 251). Therefore, based on the conclusions, modifications on the activities of the method performed to obtain the specific PSS BPA are applied if necessary as judged by the researcher. This indicates the necessity of improving the action, which may trigger a new cycle of the action research.

When the Evaluate activity identifies that no further modifications in the company's PSS BPA are necessary, then no more modifications on the method for developing the PSS BPA are necessary. Hence, the *Final PSS BPA Development Method (D.3.3)* as well as the *Specific PSS BPA (D.3.4)* for the company involved in the action research are determined. Results of the *Evaluate action (A.3.5)* of each action research cycle are described in sections 4.2.4, 4.3.3, and 4.4.3.

2.2.3.4 How to introduce objectivity and quality into action research?

A dilemma surrounding action research is how to validate its results and guarantee its objectivity considering that it is not a positivist science. According to Coughlan and Coghlan (2009, p. 259), in the case of action research, the term "validity" should be replaced by "quality".

There are four aspects for assessing quality in action research (LEVIN, 2003, p. 278): participation; real-life problems; joint meaning construction; and workable solutions. From those aspects and from other information found in action research literature, some best practice attitudes were identified and incorporated by the researcher in this study as a means to embed quality and more objectivity in this action research:

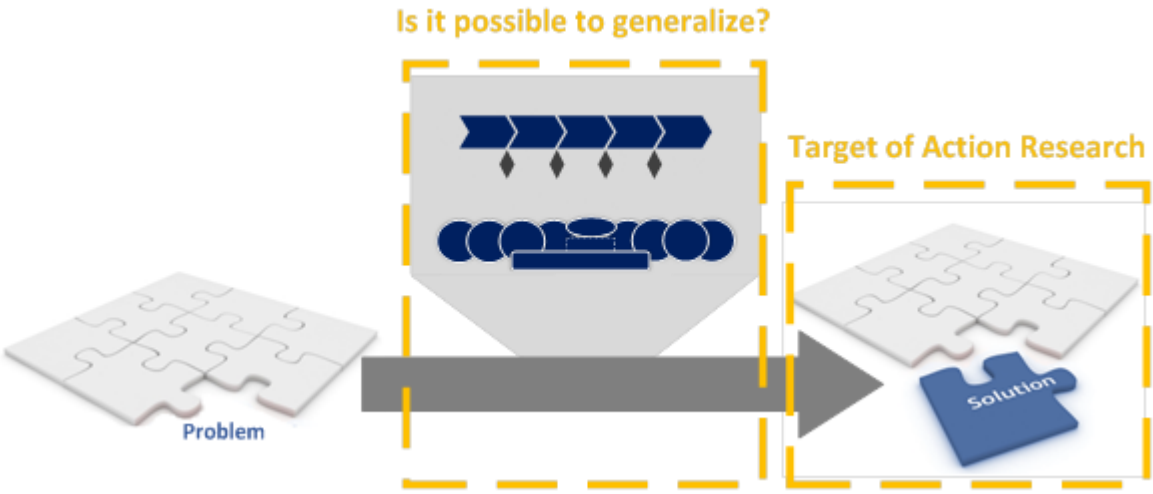
- Note observations and experiences in a research notebook or journal (COUGHLAN; COGHLAN, 2009, p. 257);
- Meta-learning: promote constant and iterative reflection as part of the organizational change (COUGHLAN; COGHLAN, 2009, p. 256);
- Have theoretical and practical understanding of theory in order to reflect on results (COUGHLAN; COGHLAN, 2009, p. 257);

- Identify the ends, values, and norms of the organizational context, in order to understand his own preconceptions and the preconceptions of the company's members when reflecting about the solution (GILL; JOHNSON, 2002, p. 93);
- Empathetic understanding behavior: apply collaborative research methods, such as non-directive interviews and observations (GILL; JOHNSON, 2002, p. 92), as described in section 2.2.3.3.2;
- Use triangulation approach and apply different techniques concomitantly (YIN, 2011, p. 147), as described in section 2.2.3.3.2;
- Combine inquiry and advocacy in order to form inferences (COUGHLAN; COGHLAN, 2009, p. 257);
- Present inferences in public (to the members of the company) for critique, discussion, and testing (COUGHLAN; COGHLAN, 2009, p. 257).

2.2.3.5 Action research and generalization

As already mentioned in the previous sections, action research's main objective is to determine a solution for a specific problem. Nevertheless, during the process of the action research, methods are applied to address the problem and achieve the solution, as depicted in Figure 8.

Figure 8 - Functioning of action research



SOURCE: created by the author.

According to Gill and Johnson (2002, p. 94), generalizations about the contributions of the methods applied for solving the problems may be made, until a limited extent. This occurs specially when there is clear evidence of patterns that could have wider applicability. Still according to those authors, an analysis of the interactions of the researchers with the members of the company in each phase of the action research could support identifying these potential contributions of the methods to the proposal and implementation of the specific solution.

Nevertheless, Gill and Johnson (2002, p. 94) emphasize that since the findings are originated from a single case, they should always be qualified with a warning note that they were obtained in a specific context. According to them, there is no doubt that many aspects and issues regarding the application of the methods need further testing against other organizational contexts, but this preliminary analysis from the action research process is a first step of an exploratory study on which other researches might build.

In accordance to that, the results of this study cannot be generalized, however first steps to prepare the path for future generalization of the solution occurs in the Descriptive Study II, as described in the following section.

2.2.4 Descriptive Study II (DS-II)

As indicated by Blessing and Chakrabarti, a full evaluation of the proposed PSS BPA Development Method is not possible in this work due to constraints in the duration of

a Masters' research project. A complete evaluation requires monitoring the complete implementation of the servitization process in the studied company and the application of the method in other cases of servitization, which may take more than a year. However, it is important to evaluate at least some of the application of the solution in terms of its applicability, usability and if possible usefulness. Hence, this stage consists of an Initial Descriptive Study II. The usefulness aspect is not accessed in this study.

The objective of including this stage of the type Initial Study in this research represents only a preliminary step in ensuring credibility for the solution, before it can be assessed by experts, validated through case studies, and finally generalized in further researches. It is important to highlight that this stage does not focus on measuring the success of the developed PSS BPA Development Method (which is part of a Comprehensive DS-II), and therefore, its results cannot be generalized (BLESSING; CHAKRABARTI, 2009, p. 184)

As already mentioned in section 2.1, according to Blessing and Chakrabarti (2009, p. 195), the Descriptive Study II occurs partially in parallel with the Prescriptive Study as a consequence of using action research. A pre-requisite to perform Descriptive Study II stage is evaluating the results generated by the proposed method for a single case, which is previously performed in activity A.3.5 as presented in section 2.2.3.3.5. Differently from the activity *Evaluate Action (A.3.5)*, which intends to verify if the outcomes generated by the proposed PSS BPA Development Method fulfills the original requirements for a specific context, Descriptive Study II focus on verifying the applicability and usability of the set of techniques, actions, and tools employed for solving the company's problem, which in this case is the PSS BPA Development Method.

This stage should answer questions such as:

- [Applicability] Do the users understand the method?
- [Usability] Can they use it?

In order to answer those questions, collaborators from the company that participated in the action research evaluate the *Final PSS BPA Development Method (D.3.3)*. The aforementioned questions are inquired to the participants, and their feedbacks are recorded, documented as transcripts, and then analyzed in order to identify potential improvements in each part of the method. As previously mentioned in section 2.1 and

indicated by the black dotted arrows in Figure 5, this task is performed in parallel with the Prescriptive Study stage.

This stage results in two deliverables:

- *(D.4.1) An indication of the applicability and usability of the PSS BPA Development Method*;
- *(D.4.2) An indication of the issues that require detailed evaluation and a suggestion for a full Evaluation Plan*.

3 Literature review

This chapter presents the theoretical background that supports the design of the PSS BPA Development Method proposed in this study. It is a deliverable (*(D.2.1) Literature Review*) of the second stage of this research, as described in section 2.2.2.1.

First, the themes PSS and servitization are explored in order to establish the basic assumptions that are considered in this work, regarding definition, concept, and typologies. Additionally, topics such as methodologies for PSS design, challenges related to the business model transformation required for PSS provision, PSS architecture, and PSS business process elements are investigated and analyzed. The objective of such analysis is to identify opportunities of connecting PSS development with business process architecture approach (BPA).

The second theme of the literature review, BPA, is also explored as a means of identifying fundamental terminology, basic definition, concept, and typologies. Also, possible methods commonly applied in BPA, pre-requisite elements that compose a BPA, and process modeling foundations such as business process reference models, modeling languages and tools are identified and analyzed in order to support the creation of the PSS BPA Development Method.

3.1 Product-Service Systems and servitization

3.1.1 PSS and servitization definitions

The term Product-Service System (PSS) was first introduced by Goedkoop et al. (1999) in the late 1990s (BAINES et al., 2007, p. 1545; BOEHM; THOMAS, 2013, p. 245; TUKKER, 2015, p. 81). Since then, its use was disseminated between the 2000s and the early 2010s by the engineering & design, computer science, business & management, and the environmental sciences academic communities (BAINES et al., 2007, p. 1546; BOEHM; THOMAS, 2013, p. 249; TUKKER, 2015, p. 77).

To explain better the concept of PSS, Goedkoop et al. (1999, p. 17) defined each element. According to him, a “product”[15] is a tangible good able to be manufactured and sold to satisfy users’ needs. A “service” is an activity or work done for others and

[15] The term “product” is frequently used, sometimes interchangeably, with the meaning of both physical goods and services (ULRICH; EPPINGER, 2012, p. 2). This study adopts the definition by Goedkoop et al. (1999, p.17) that differentiates product and services as two types of commercial offers.

worth an economic value. Finally, a “system” is a collection of elements, which includes their relations.

After the work of Goedkoop et al. (1999), several definitions for PSS were proposed in literature. Boehm and Thomas (2013) presented a state-of-the-art study on PSS research, and by performing a systematic literature review with 265 articles, they proposed the following common definition for PSS: “A Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value” (BOEHM; THOMAS, 2013, p.252). Tukker (2015, p. 87) corroborates with this definition by indicating that different researchers have been converging to it for over a decade, however, there is still need for an effort from the PSS community towards standardization and formalization of a concept. This study embraces the definition by Boehm and Thomas (2013), as their review was broad and encompassed scientific rigor.

Although PSS is the most recurrent term on literature (BOEHM; THOMAS, 2013, p. 251), different scientific research communities employ other labels with similar meaning, such as “Industrial Product-Service Systems (IPS2)” (MEIER; ROY; SELIGER, 2010; MÜLLER; STARK, 2010; WELP et al., 2008), “Integrated Product and Service Offering (IPSO)” (LINDAHL; RÖNNBÄCK; SAKAO, 2009), “Total Care Products” (ALONSO-RASGADO; THOMPSON, 2006), “Technical Services” (AURICH; FUCHS; WAGENKNECHT, 2006), Eco-efficient services (BREZET et al., 2001), and “industrial services” (GEROSA; TAISCH, 2009). This study adopts the term PSS in accordance with Boehm and Thomas (2013).

The expression “servitization” is frequently related to PSS concept, however it presents a different meaning than PSS (BAINES et al., 2009a, 2009b; DAHMANI; BOUCHER; PEILLON, 2013; OLIVA; KALLENBERG, 2003; PARK; GEUM; LEE, 2012; VANDERMERWE; RADA, 1988). Servitization was first mentioned and defined by Vandermerwe and Rada (1988, p.314) as the increasing “offering of fuller market packages or ‘bundles’ of customer-focused combinations of goods, services, support, self-service and knowledge”. Baines et al. (2009a, p.555) performed a systematic review on servitization and proposed an updated definition: “Servitization is the innovation of an organization’s capabilities and processes to better create mutual value through a shift from selling product to selling PSS”. Those definitions have different meanings as they are originated from different perspectives. For Vandermerwe and

Rada (1988, p.414), servitization is defined by an “action” towards an objective, which in this case is the “movement” towards offering PSS. On the other hand, Baines et al. (2009a, p.555) associate servitization with “the means” for performing “the movement towards PSS” and achieving an objective, which in this case is “the transformational process performed by organizations when they move from manufacturing to PSS business models”.

This study adopts the definition of Baines et al. (2009a, p.555), and employs the term servitization to mean, “manufacturing companies’ transformational process into PSS providers”.

3.1.2 PSS concept

One major difference of PSS when compared to traditional manufactured offerings lies on the fact that “a client[16] demand is met by selling satisfaction instead of providing a product” (MANZINI; VEZZOLI, 2003, p.851). This means that in some situations, the acquisition or consumption of a physical result of an industrial process is not sufficient anymore to fulfill market needs (TUKKER; TISCHNER, 2006, p. 1552). Instead, some types of products are being interpreted as means to provide a function, and therefore, they are combined to services in order to generate value for both customers, providers, and their network of partners (CESCHIN, 2013, p. 74).

Another difference pointed out by many authors is the necessity of redefining or creating a new business model when designing a PSS (BARQUET et al., 2013, p. 693; GEBAUER; BRAVO-SANCHEZ; FLEISCH, 2007, p. 20; TAN, 2010, p. 242; TUKKER; TISCHNER, 2006, p. 1552). One of the main challenges for organizations aiming to become PSS providers is to identify and perform the changes required in their businesses (MARTINEZ et al., 2010, p. 461; OLIVA; KALLENBERG, 2003, p. 161).

PSS approach generates several business benefits for the providers, such as potential economic improvements (recurrent income, increase in revenue, and potential increase in profit) (NEELY, 2009, p. 114), market differentiation and increased customer satisfaction and retention (BECKER; BEVERUNGEN; KNACKSTEDT, 2010, p. 40).

[16] PSS clients comprise mainly other enterprises in the case of Business-to-Business (B2B) transactions, or final customers, in the case of Business-to-Customer (B2C) transactions (TRAN; PARK, 2015, p.1). Even in PSS oriented to B2B market, depending on the type of services provided, it is important to identify and consider the end users’ interactions with the PSS (or the B2B2C chain) during its design phase.

Furthermore, some authors associate PSS concept to a potential in reducing environmental impacts (BAINES et al., 2007, p. 1545; GOEDKOOP et al., 1999, p. 18; MONT, 2002, p. 238) since, if properly designed and implemented, PSS enables decoupling economic returns from material and energy consumption (MANZINI; VEZZOLI, 2003, p. 851; MONT, 2004, p. 911; TUKKER; TISCHNER, 2006, p. 1553).In order to determine how to conceptualize a PSS, Tan (2010, p. 205) identified seven strategic characteristics of a PSS, as described in Table 4:

Table 4 - PSS strategic characteristics

PSS strategic characteristics	Meaning
1. Resource efficiency strategy	Material and energy strategy adopted in the PSS to reduce environmental impacts of the product throughout its life cycle.
2. Responsibility or management of product life	Who detains the ownership of the product and responsibility for traditional activities related to the product's use phase such as installation, operation, and maintenance of the product (they may be responsibility of the customer or the PSS provider).
3. Support or management of customer activity	Due to specific knowledge requirement, the customer may demand additional services for handling his operational processes associated to the product, such as for example chemical management services, which require constant surveillance and meticulous documentation.
4. Partner or collaborate with actor	Type of partnerships (for example with suppliers for executing specific activities of the value chain) or collaborative relationships established by the provider for the provision of the PSS.
5. Availability of offering	The possible degree of interaction with the product enabled by ICT. This facilitates the use of the product especially in cases of sharing. For example, remote control, access to online historical data, possibility of checking availability and reserving books online in libraries.
6. Degree of integration	The extent in which other activities associated to the product use and required by the customers are satisfied by the PSS. For example, the injection of insulin is the core benefit expected by diabetics; however, they may require measuring the level of insulin, receiving warnings to remind injection times, and so on.
7. Revenue mechanism	The way in which PSS offer is charged from the customer, which can be based on the availability of the product or service, the frequency of use, or generated results.

SOURCE: adapted from Tan (2010).

According to Tan (2010, p.205), different PSS solutions are generated depending on how those seven characteristic are configured.

3.1.3 PSS typologies

Several examples of PSS have been described in literature (BAINES et al., 2007; CESCHIN, 2013; MONT, 2004; REINARTZ; ULAGA, 2007; ULAGA; KONDIS; MCTEAGUE, 2013). Typologies[17] have been created to describe the variations of PSS offers and enable researchers and practitioners in predicting PSS behaviors in order to support management decisions and actions (PARK; GEUM; LEE, 2012, p. 544).

Each PSS typology is based on different criteria or set of criteria, such as: product ownership (MEIER; ROY; SELIGER, 2010; PARK; GEUM; LEE, 2012), degree of relationship between customer and provider (MEIER; ROY; SELIGER, 2010), provider's revenue mechanism, degree of integration between product and services (CLAYTON; BACKHOUSE; DANI, 2012; PARK; GEUM; LEE, 2012), role of technology (PARK; GEUM; LEE, 2012), ratio between product and services in the offer (TUKKER, 2004), and the kind of service components in the PSS offer (ROY, 2000; VAN HALEN; VEZZOLI; WIMMER, 2005). Although Tukker (2004) typology is the most cited in literature and even indicated by some authors as the most applicable to characterize PSS (BEUREN; FERREIRA; CAUCHICK, 2013, p. 228), there is still no consensus about a standard categorization for PSS (BEUREN; FERREIRA; CAUCHICK, 2013, p. 225; TUKKER, 2015, p. 88).

This section is dedicated to explain in further details some cited typologies and compare them in order to define which one is more adequate to support the PSS BPA Development Method elaboration. As described in section 1.1, this study will focus on the situation of manufacturing companies moving to PSS business models. In such cases, since the companies already offer products, they usually have an existing developed BPA with core processes oriented to manufacturing and commercialization of physical products. Therefore, the required transformation regarding the BPA is mainly concentrated on structuring processes to support the new service components of the PSS or on modifying already existing processes, such as back-office and product manufacturing processes, in order to adequate them to PSS characteristics. For this reason, the following analysis focus on typologies based on the "kind of service

[17] Typologies are theoretical propositions of ideal categories that represent reality (METTERS; VARGAS, 2000, p.666; PARK; GEUM; LEE, 2012, p.529).

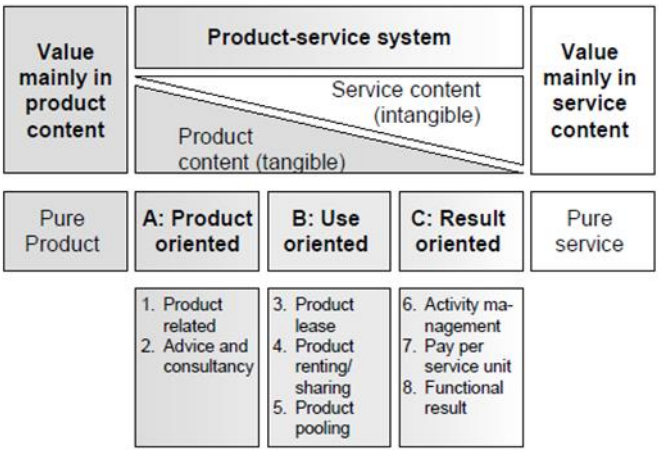
components in the PSS offer" criterion. Additionally, the typology proposed by Tukker (2004) is also explored in more details, since it is by far the most disseminated in literature.

3.1.3.1 Tukker (2004)

As this is the most cited typology, it deserves the first position for discussion in this study.

Tukker (2004) proposes eight types of PSS that are distributed in three main categories (A, B and C) according to the degree of reliance on the product or service components of the PSS offer. As illustrated in Figure 9, the dependence on the product as a core component of the PSS decreases from the first to the third category. At the same time, the offer becomes more abstract, which increases the risks for both provider (by not being able to concretely determining what is going to be delivered) and customer (by not knowing exactly what he will receive) (TUKKER, 2004, p. 249). Each type of PSS is explained in details below.

Figure 9 – Eight types of PSS



SOURCE: Tukker (2004).

Product-oriented services

It involves the traditional sale of a product with the possibility of the provider offering and selling additional services to guarantee functionality and durability of the product. In this case, the consumer detains the ownership over the product and benefit with reduced costs during the use phase. The two types of PSS in this category are (TUKKER, 2004, p. 248):

- *Product related services*, such as maintenance and repair;

- *Advice and consultancy services*, that can support customers on operating and extending the product's life cycle such as trainings.

Use-oriented services

In this configuration, the provider sells product function or availability to customers that pay for it in different ways. The providers keep the ownership of the products. This motivates them to maximize the product life cycle by using more durable materials, providing services for extending product's life cycle, and rethinking end of life strategies. The types of PSS in this category are (TUKKER, 2004, p. 249):

- *Product lease*, in which customers pay a regular fee for using the product unlimitedly and generally individually during a certain period.
- *Product renting or sharing* is a similar purpose as *product lease*, except for the fact that more than on user share product's use sequentially. Payment may be a function of the amount of time of usage by each customer or of the events of service consumed.
- *Product pooling* is a special case of *product renting* in which different customers use the product simultaneously.

Result-oriented services

In this PSS category, there is no pre-defined offer. Instead, provider and customer mutually agree on an outcome or solution to be commercialized. The provider holds the product ownership and charges for the delivered solution. The types of PSS in this category are (TUKKER, 2004, p. 249):

- *Activity management* involves the customer outsourcing some activities to third parties, such "as catering and cleaning".
- *Pay per service unit* still considers the product as a basis, however the product's ownership is kept with the provider and the customer pays for the outputs of the product, such as number of drinks in a coffee machine.
- *Functional result*, customer and provider agree on a specific functional outcome, but the provider is free in the way of delivering the solution. One example is providing "constant pleasant climate" instead of selling air conditioner or heaters.

Although this typology is the most cited in literature, it presents some limitations that are described below.

The first limitation is that Tukker's typology is purely descriptive in the sense that it is based on describing examples of each PSS variation without clearly specifying common criteria (for example, product ownership, revenue model, technology dependence, level of integration of product and services) that could be used as a checklist to compare PSS types (TAN; MCALOONE, 2006, p. 2). This characteristic may generate confusion and ambiguity, since without explicit parameters the classification becomes dependent on each person's interpretation of the PSS scenario.

Another limitation is that Tukker's approach considers only one dimension of the PSS design, which is the configuration of the system in terms of "what" is delivered in the PSS regarding the reliance on the product or service components. Consequently, it neglects other important PSS information, such as value delivery regarding environmental benefits. Moreover, this approach seems to have limited practical application for industries that are trying to implement PSS, because it focus on describing features and examples of the offer (what is the offer) instead of exploring intrinsic values (what are the benefits delivered) (BAINES et al., 2009b, p. 9; TAN; MCALOONE, 2006, p. 2).

Additionally, although Tukker (2004) depicts the service transition phenomena as a linear product-PSS continuum in Figure 9, he only defines eight discrete types of PSS. According to Kowalkowski et al. (2015, p. 65), Tukker's representation is not adequate, as the behavior of service transition is more "multifaceted" and "multidirectional". Multifaceted means that multiple types of servitization (beyond eight) may occur depending on the context (market opportunities or customer requirements). Multidirectional means that different servitization trajectories beyond the linear transition from product to PSS provider may occur. To cite one example, instead of completely transitioning to PSS business models, companies can simply expand their portfolio by adding services or PSS offers complementarily to their traditional offers.

Finally, this typology has been created for more than a decade and the PSS theory has evolved considerably since then (BEUREN; FERREIRA; CAUCHICK, 2013, p. 224; BOEHM; THOMAS, 2013, p. 249; TUKKER, 2015, p. 78). Hence, there may exist a need for updating the perspectives in Tukker's typology with the state of the art theory and advances in practice in the PSS field.

3.1.3.2 Roy (2000)

Roy (2000, p. 293) is the second most cited reference of PSS typologies. He defines four types of PSS based mainly on the nature of services and their intention to reduce environmental impacts:

- Result services: aims at decreasing material consumption by selling result instead of a physical good. In general, the provider keeps the ownership of the product, and therefore, he is responsible for maintaining, disassembling, and handling the products' end of life.
- Shared utilization services: aims at maximizing the use of materials by sharing the product component of the system with different customers.
- Product life extension services: aims at extending the useful life of products and reduce material and energy consumption by means of providing maintenance, repair, reuse and recycling services.
- Demand side management: these are similar to "result services" type and are related to managing the customers' consumption in order to reduce material and energy consumption.

3.1.3.3 Van Halen, Vezzoli, and Wimmer (2005)

Van Halen, Vezzoli and Wimmer (2005, p. 22) propose four types of PSS according to the nature of services:

- Product-oriented services: **"**provide customers with the use of the product for a limited period" and may include additional services. Examples are lease, car sharing and rental.
- Knowledge-oriented services: provide intellectual support and capacitates the customer. Examples are training and consultancy.
- Labor-oriented services: similar to outsourcing of specific activities, such as cleaning services.
- Result-oriented services: provide customers with specific result instead of specific product. These services combine all other categories by involving information and labor provision to achieve results. Examples are energy saving contracts, and Rolls Royce's power-by-the-hour program.

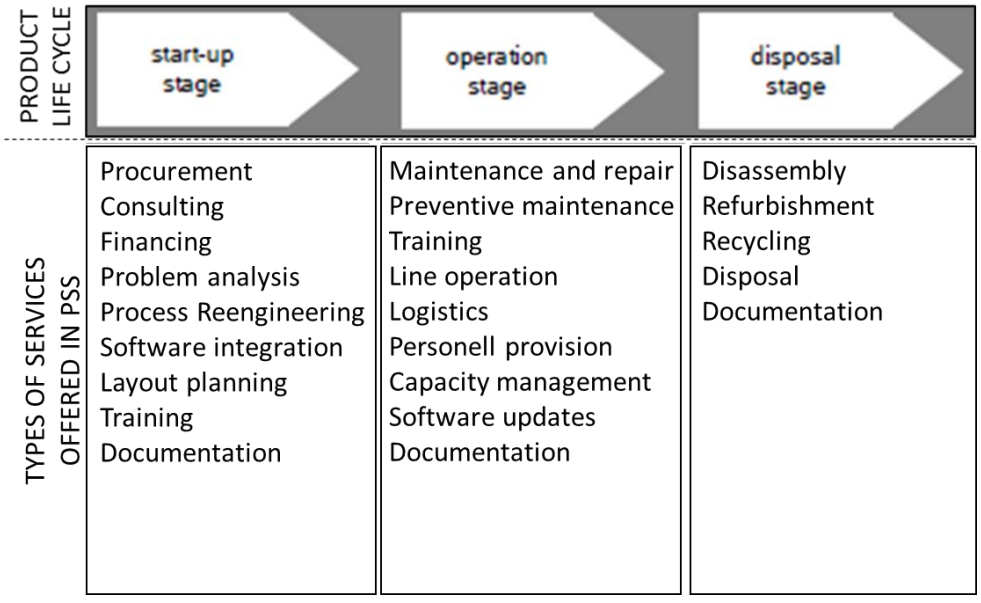
3.1.3.4 Becker, Beverungen, and Knackstedt (2010; 2008)

Based on the concept that companies intending to provide a PSS may offer services of different natures along the product life cycle, these authors propose three clusters of PSS services:

- Start-up stage services: related to pre-commercialization activities, such as consulting, financing, and procurement.
- Operation stage services: activities conducted during the use phase to ensure PSS availability and boost the customers' profitability results, such as maintenance, line operation, training, and retrofit.
- Disposal stage services: related to the product's end of life or to the end of the PSS contract, such as disassembly and recycling.

Different examples of services from each category are illustrated in Figure 10.

Figure 10 – PSS services along product life cycle



SOURCE: adapted from Becker, Beverungen and Knackstedt (2010, 2008).

3.1.3.5 Meier and Krug (2009)

Meier and Krug (2009, p.312) indicate seven types of relevant services in capital goods that can be applied to PSS field. Those clusters are also related to the nature of service, as described below:

- Planning services, such as material flow and factory planning;
- Counseling services, such as personnel counseling;
- Training services, such as collaborator training;
- Logistic services, such as machine implementation;
- Function creating services, such as ramp-up management;
- Function maintaining services, such as maintenance, repair, and overhaul;
- Optimizing services, such as process optimization.

3.1.3.6 Comparison of PSS typologies

Table 5 summarizes the main characteristics of each typology presented previously in sections 3.1.3.1, 3.1.3.2, 3.1.3.3, 3.1.3.4, and 3.1.3.5.

All of them are simplistic in the sense of being established around only one central criterion. However, they seem to be complementary, as different perspectives and potentials are explored in each classification. For example, Tukker (2004) typology enables the provider to predict and plan an evolutionary transformational path by moving and sophisticating PSS offer along the range between pure product and pure service. Becker, Beverungen, and Knackstedt (2010; 2008), explores an interesting aspect that is the services' profile along the product life cycle, which facilitates the management and operationalization of business processes to support services' provision. Roy (2000) explores the environmental potential aspect by employing it as a pre-requisite to configure services.

Therefore, aiming at covering the gap and inspired by examples of matrix-structured classifications with two or more criteria (PARK; GEUM; LEE, 2012; SILVESTRO et al., 1992), this study proposes a combination of two typologies illustrated in Figure 11. The first and central typology (on horizontal axis) is an adaptation of Becker, Beverungen, and Knackstedt (2010; 2008) and Meier and Krug (2009), with the perspective of service portfolio[18] offer along the PSS life cycle (BOL, MOL and EOL phases). The second typology (on vertical axis) is Tukker (2004), which contributes by enabling planning and evolutionary path for PSS transformation, which is fundamental in case of manufacturing companies moving to PSS business models. The vertical axis

[18] The collection of services embedded in the PSS offer.

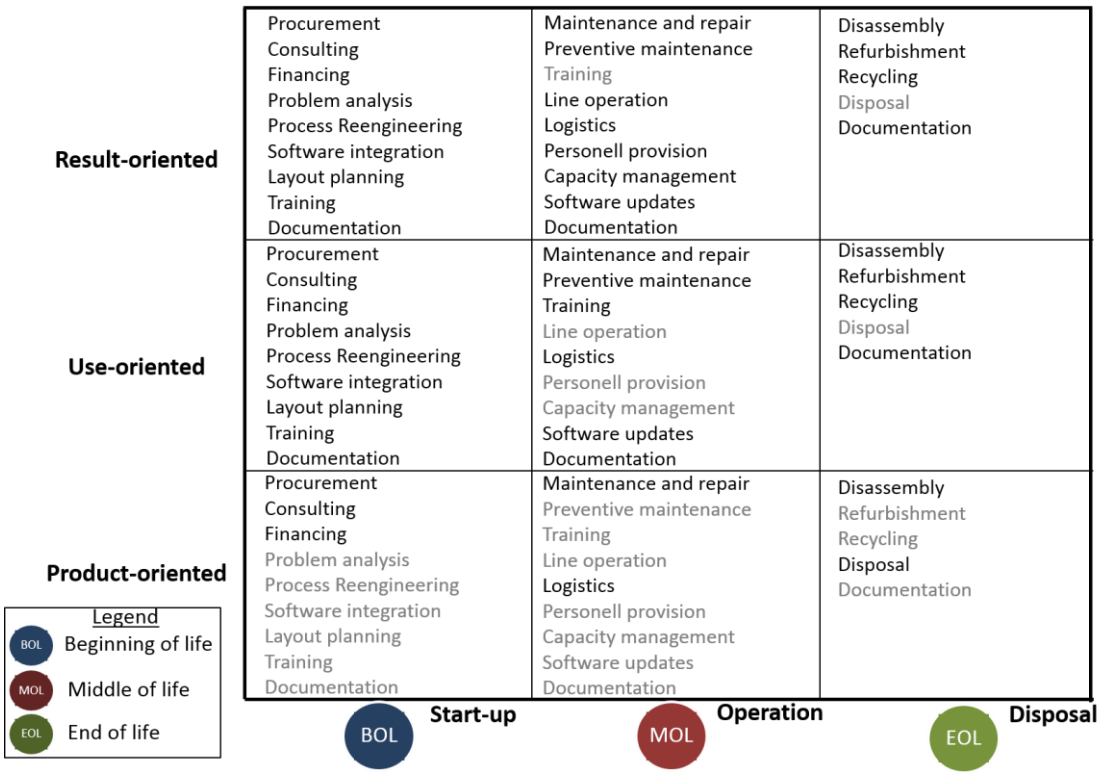
represents then the evolutionary moments of a PSS offer. The gray words in the figure indicate the types of service that have a lower probability of occurring in each evolutionary moment.

Table 5 – Comparison of PSS typologies

	Tukker (2004)	**Roy (2000)**	**Van Halen, Vezzoli, and Wimmer (2005)**	**Becker, Beverungen, and Knackstedt (2010; 2008)**	**Meier and Krug (2009)**
Classification criteria	Degree of reliance on product component	Nature of services for improving environmental aspects	Nature of services	Nature of services along product life cycle	Nature of services in capital goods
PSS types	8	4	4	3	7
Strengths	• Most cited • Notion of evolutionary sequence (provider transformation path)	• Considers environmental aspects	• Notion of evolutionary sequence (provider transformation path)	• Relate services to the product life cycle stages facilitating the management of service or value provision	• Rich in examples
Limitations	• Simplistic (only one criterion) • Linear transformation • Lack important aspects of PSS • Limited practical application	• Simplistic (only one criterion) • Absence of provider's transformation "path" • Few examples of services in each category	• Simplistic (only one criterion) • Few examples of services in each category	• Absence of provider's transformation "path" • Simplistic (only one criterion) • Space for more examples of services in each phase	• Simplistic (only one criterion) • Specific to use-phase • Lack important aspects of PSS

SOURCE: created by the author.

Figure 11- Adopted PSS typology



SOURCE: adapted from Becker, Beverungen, and Knackstedt (2010; 2008), Meier and Krug (2009), and Tukker (2004).

3.1.4 Business model transformation

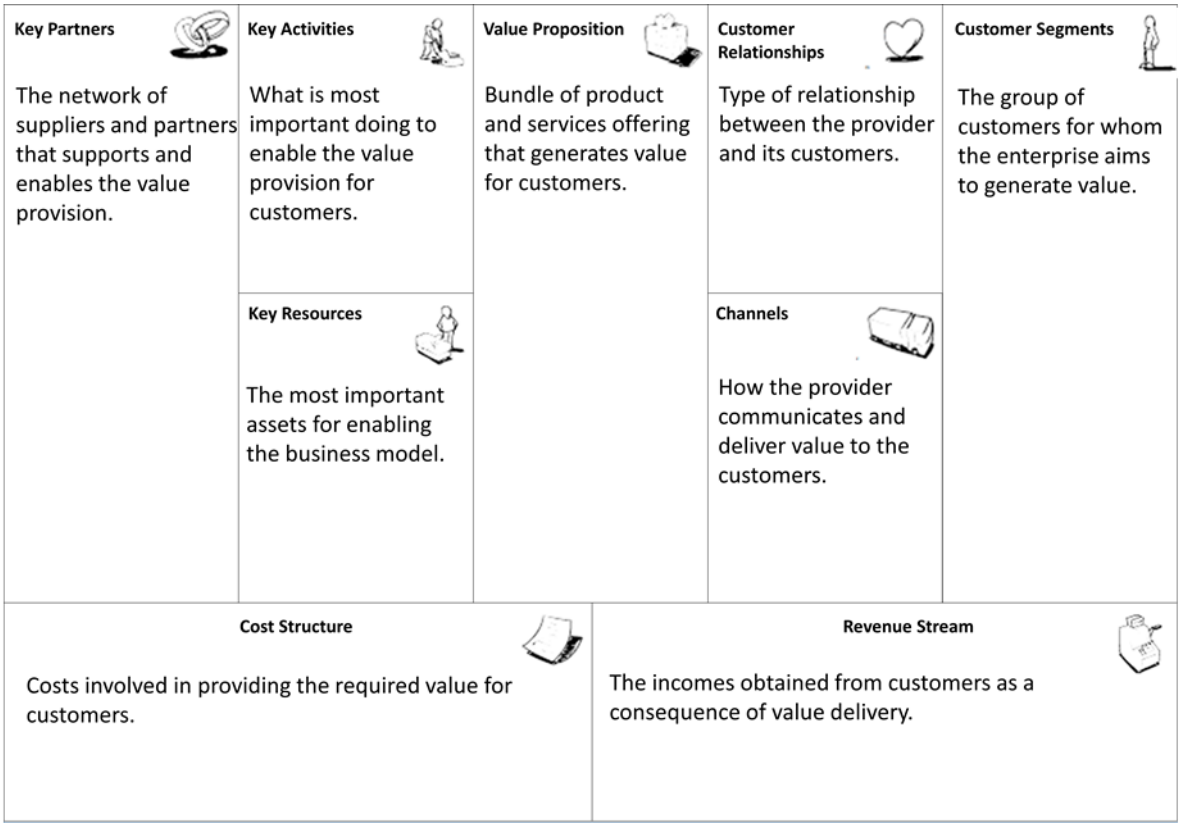
Business models are representations of the organization's logic to create and deliver value to customers (OSTERWALDER; PIGNEUR, 2010; SHAFER; SMITH; LINDER, 2005; TEECE, 2010; WIRTZ et al., 2015). Depending on the author, this representation may depict different elements (called "dimensions" in this work), such as the company's strategic choices, operations and relationships (BARQUET et al., 2013).

One of the most referenced representations is the Business Model Canvas (BMC) (OSTERWALDER; PIGNEUR, 2010). This framework may be applied for designing new or existing business models in different industries. It is based on nine business dimensions: customer segments, value proposition, channels, customer relationship, key activities (this work adopts the term "key processes"), key resources, key partnerships, costs, and revenues. Figure 12 illustrates the framework and brings an explanation for each dimension.

As highlighted in section 3.1.2, designing a PSS involves either creating a new business model, in cases of start-ups, or altering existing business models, in cases of

companies already in operation with traditional product or services. A manufacturing company aiming to provide a PSS fits the last situation, and consequently, need to transform its business model or the business model of certain business unit towards a service oriented perspective (BARQUET et al., 2013; TAN, 2010; TUKKER; TISCHNER, 2006), which characterizes the servitization process.

Figure 12 - Business Model Canvas framework



SOURCE: adapted from Osterwalder and Pigneur (2010).

Servitization is complex and affects several business elements such as corporate culture, organizational structure, performance and reward systems, business processes, and the relationship with customers, suppliers and stakeholders (GEBAUER; BRAVO-SANCHEZ; FLEISCH, 2007; NEU; BROWN, 2005; OLIVA; KALLENBERG, 2003).

The degree of transformation and complexity required for PSS business model transitions varies depending on the company's strategy and risk sensitivity (ALONSO-RASGADO; THOMPSON, 2006, p. 513). There are four potential scenarios:

- Scenario 1 comprises both product and services components of the PSS as novelties (BARQUET, 2015; BARQUET et al., 2013). In this case, product and

services should be developed simultaneously from the beginning, which increases business risks.

- Scenario 2 includes offering existing product and services, which results the minimum risk combination.
- Scenario 3 considers a new product with an existing service platform (WRASSE; HAYKA; STARK, 2016).
- Scenario 4 encompasses an existing and fully developed product combined with new services platform (BARQUET et al., 2013; BOUCHER; PEILLON, 2015; KOWALKOWSKI et al., 2015; OLIVA; KALLENBERG, 2003).

The focus of this study is “scenario 4”. In such cases, the PSS development process is concentrated on the services. Nevertheless, the design method should also evaluate if the product has necessary functionalities to enable the PSS offer or if it requires modifications (adjustments in hardware to enable automatic billing, installation of sensors to monitor customer’s operation and enable predictive maintenance, or product modifications to satisfy customer’s new requirements).

There are two variations of “scenario 4”. Some companies may choose to operate only with PSS business model while others may operate both traditional and PSS business models in parallel. In other words, they can continue selling traditional products and the integrated product service solution concomitantly in order to expand their market share and gain access to new markets (CLAYTON; BACKHOUSE; DANI, 2012, p. 272; KOWALKOWSKI et al., 2015). For this last scenario, many organizations choose to open a subsidiary company for operating the PSS in order to avoid harming their original brands (especially when remanufacturing or refurbishment are involved in the PSS strategy), facilitate the attraction of funding from investors, and to avoid internal competition between salesforce (MONT; DALHAMMAR; JACOBSSON, 2006).

Regardless of the chosen scenario, the formation of partnerships is pointed by many authors as one strategic characteristic for PSS business models (BAGHERI; KUSTERS; TRIENEKENS, 2014; TAN, 2010). Due to its relevance, this topic is discussed in details in the following section 3.1.5.

3.1.5 Partnership network potential

As highlighted in sections 3.1.2 and 3.1.3.6, providing PSS changes the business domain of the provider that assumes some of the activities that were previously performed by the customer or other suppliers in the value chain. This demands new skills and capacities from the manufacturing companies that may need to establish partnerships to fulfill those requirements. In fact, many authors associate the establishment of collaborative partnerships as a core condition and positive differential of providing PSS (ANDERSEN et al., 2013a, p. 12; CESCHIN, 2013, p. 77; KRUCKEN; MERONI, 2006, p. 1502; MANZINI; VEZZOLI, 2003, p. 856; MORELLI, 2006, p. 1500). By promoting convergence of economic interests between the stakeholders in the network, PSS promotes the reduction of resources' consumption, which decrease costs and reduce environmental impacts.

Despite those benefits, there are uncertainties, risks, and trade-offs involved in partnerships that may be potential barriers and challenge the implementation of value networks for PSS provision (ANDERSEN et al., 2013a; CESCHIN, 2013; DURUGBO, 2013). Some examples of such barriers are: conflicts of interests, trade secrets, intellectual properties, insurance issues, loss of flexibility, sharing of core information about customers (ANDERSEN et al., 2013a, p. 21).

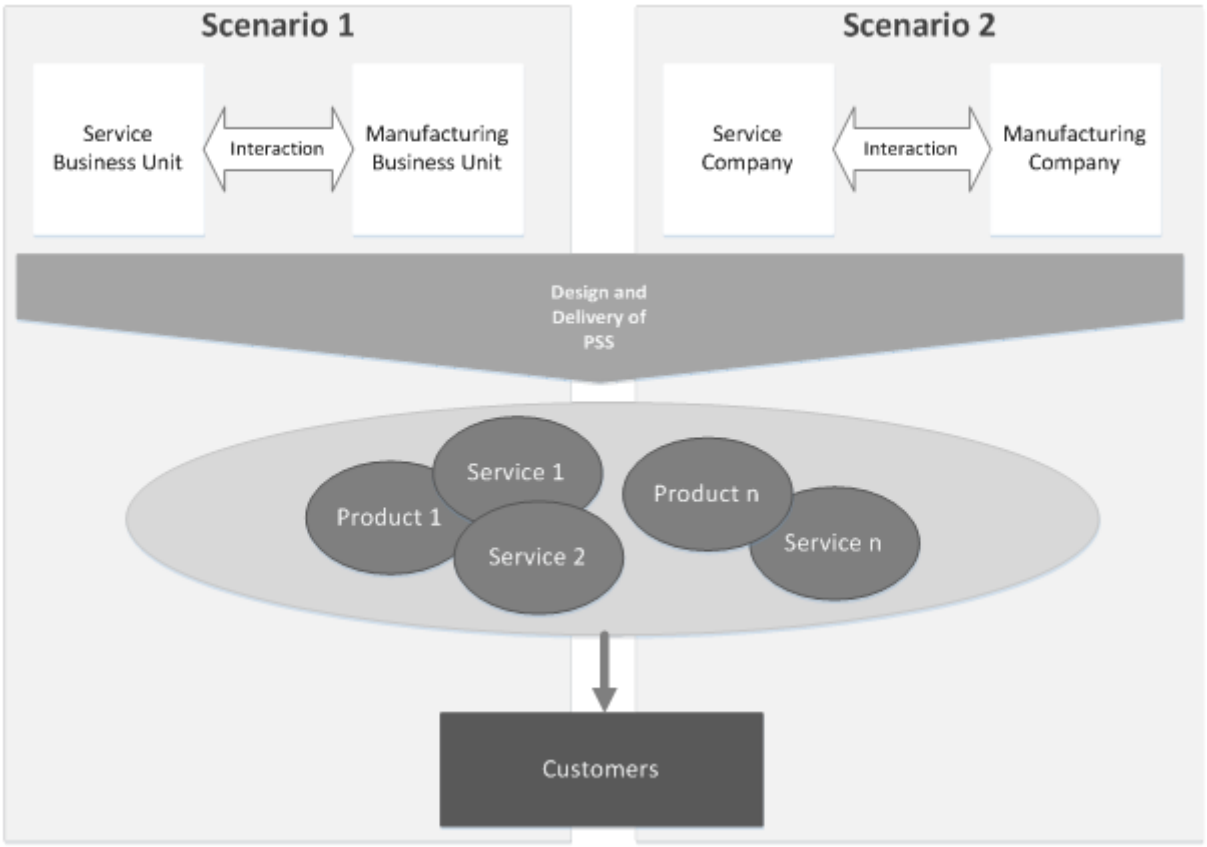
Therefore, PSS design and offer may occur either by a single company providing the complete value proposition or by collaborative[19] value network of companies (BECKER; BEVERUNGEN; KNACKSTEDT, 2010, p. 44; GOEDKOOP et al., 1999, p. 18).

Figure 13 illustrates these two possible scenarios of PSS provision: (1) one company providing both products and services components of the system; (2) two or more companies providing the components of the PSS in a value network (BECKER; BEVERUNGEN; KNACKSTEDT, 2010, p. 44). According to Andersen et al. (2013, p.17), three possible network arrangement may occur in the second scenario depending on the degree of innovation and type of interaction between the partners

[19] Although "cooperative" and "collaborative" are frequently used interchangeably, they have different meanings. Collaborative relationships are synonym for partnership. They involve the jointly participation of two or more actors (individuals or organizations) in designing, producing and commercializing a product or process for mutual benefit. On the other hand, cooperative relationships involve two or more actors that reach a formal or informal mutual agreement but not necessarily working together or aiming at mutual benefit or similar goals (HORD, 1981,p.3; POLENSKE, 2004, p.1031). PSS value networks are formed only when collaborative relationships are present (ANDERSEN et al., 2013, p.15).

promoted by the PSS. The first network arrangement is characterized by interactions limited to communication and procurement activities, which is already present in current businesses more oriented to product offer. A second arrangement pushes the level of trust involved in the network's relationships by involving exchange of data, legal contracts, and mutual support. Finally, the third arrangement reaches the highest scale of trust and collaboration by adding interactions in the sphere of co-development, risk sharing, platform sharing and co-financing (ANDERSEN et al., 2013a, p. 18).

Figure 13 - Scenarios of PSS provision



SOURCE: adapted from Becker; Beverungen; Knackstedt (2010, p.44).

To sum up, analogously to the "make or buy" decision from the manufacturing product development literature (COOPER; SLAGMULDER, 2004, p. 3), when designing its business model, the PSS provider has to balance its gaps, opportunities, and risks in order to take the decision whether to establish partnerships for providing some parts (either a service or components of the product) of the system or not. Andersen et al. (2013, p.40) suggest the following activities for building required partnerships in PSS servitization: understand required capabilities for offering the intended PSS, which may

be supported by User Activity Cycle (UAC)[20] method; identify network capabilities and deficiencies, and search for potential partners.

3.1.6 Methodologies for PSS design

3.1.6.1 Fundamental terminology for analyzing PSS design methodologies

Approaches for PSS design, such as the one discussed in the subsequent section 3.1.6.2, refer to methodology, method, model or framework without a clear definition or distinction between them. This study considers the following definitions:

1. Method (technique) is a systematic procedure using a sequence of steps[21] to execute an activity[22], permitting the use of one or more tools (EDER et al., 2012; PMI, 2013, p. 563).
2. Tool is a tangible artifact used to support the execution of an activity within a method context (PMI, 2013, p. 564).
3. Practices are “a specific type of professional or management activity that contributes to the execution of a process[23] and that may employ one or more techniques and tools” (PMI, 2013, p. 551).
4. Methodology is an association of practices, methods and tools (EDER et al., 2012; PMI, 2013, p. 573)
5. Model is a simplified representation of reality. Models “facilitate description and optimization of organizational issues such as business process[24]” (FETTKE; LOOS, 2003, p.35). They may encompass practices of a determined context that can be generic or specific (FETTKE; LOOS, 2003, p. 37).
6. Framework, “in process modeling, is any planned association among the models applied to meet a policy, design, or usability requirement” (CBOK, 2013, p. 431).

[20] User Activity Cycle (UAC) is a method applied to identify users’ needs along the whole product life cycle (before, during, and after use phase (HELLEK et al., 2013, p.32).
[21] For the definition of step, consult section 3.2.1.
[22] For the definition of activity, consult section 3.2.1.
[23] For the definition of process, consult section 3.2.1.
[24] For the definition of business process, consult section 3.2.1.

3.1.6.2 Evaluation of PSS design methodologies

Different methodologies[25] were proposed for designing PSS. Clayton, Backhouse and Dani (2012), Qu et al. (2016) and Vasantha et al. (2012) have performed studies comparing different PSS design methodologies, and providing conclusions and orientation for further research. Table 6 summarizes the characteristics and outcomes of each study.

Table 6 - Assessment studies of PSS methodologies

	Clayton, Backhouse and Dani (2012)	**Vasantha et al. (2012)**	**Qu et al. (2016)**
Objective	Evaluate representativeness of literature in suggesting PSS Design Methodologies	Understand research directions for PSS Design Methodologies	Develop the state-of-the-art in PSS design, evaluation, and operation methodologies
Research Method	Literature review and single exploratory case study	Literature review	Systematic literature review
Number of Assessed Methodologies	6	8	83[1]
Conclusions	• Few methodologies supporting PSS design • Methodologies do not apply to servitization process • Methodologies are incomplete • Methodologies are not iterative/incremental as PSS requires	• Methodologies do not support sustainability embedding (lack of details and incompleteness) • Methodologies are not evaluated in practical industrial application • Methodologies should be multidisciplinary	• Lack of sustainability approach (incompleteness) • Little attention on producer or cost perspective (incompleteness)
Future Researches	• Detailed assessment of completeness of approaches • Development of specific tools, methods, techniques and guidelines for creating new PSS	• Development of a unique PSS ontology • Investigation of environmental aspects in value creation/ use phase • Investigation of co-creation	• Application of existing methodologies from other disciplines to support PSS design • Exploration of sustainability • Conduction of quantitative researches

[1] These authors distinguish the methodologies in three categories: design (36), evaluation (24), and operation (23). However, since they do not present definitions of the meaning of each category, it is difficult to understand how the methodologies were classified. For instance, they seem to fit more than one category simultaneously and all of them seem to be PSS design approaches. Therefore, this study considers that all the methodologies presented are applicable to the design phase of the PSS life cycle.

SOURCE: created by the author.

[25] For means of generalizing and facilitating communication, this study considers that all approaches presented by the three authors can be referred to as methodologies. Since a model comprises a group of practices that involves one or more methods and tools, then models can be interpreted as methodologies.

To sum up, the main conclusions were:

1. Existing methodologies are in general incomplete, provide partial solutions with low degree of details, and are not incremental (CLAYTON; BACKHOUSE; DANI, 2012, p.295; QU et al., 2016, p.12; VASANTHA et al., 2012, p.26);
2. They are not evaluated in the context of servitization or the transformation of manufacturing companies (CLAYTON; BACKHOUSE; DANI, 2012, p.294);
3. They tend to lack practical validation (VASANTHA et al., 2012, p.26);
4. There is an opportunity for using existing methods from other disciplines to compose PSS design methodologies (QU et al., 2016, p.12; VASANTHA et al., 2012, p.26).

These gaps were also reported in other state of the art reviews on PSS, such as the studies of Baines et al. (2007) and Boehm and Thomas (2013). In accordance with conclusion 2 and 3, those authors also identified a need for future research concerning the development of methodologies to assess value and organizational transition, and more collaboration between practitioners and researches of PSS in order to produce empirical work.

Specifically regarding PSS business model methodologies, literature indicates that the definition of a completely new PSS business model - using the Business Model Canvas or other techniques based on this approach – that usually occur in the Front-End of Innovation (FEI), stays at a conceptual level, since limited information is available until this point (ANDERSEN et al., 2013b; BARQUET et al., 2013). Therefore, such methods lack the appropriate level of details for enabling the implementation of a PSS offer based on existing products. The detailing of the business model for the servitization context may start in the very beginning of the servitization process, when the current business is being analyzed for determining the servitization opportunities, however its complete definition only occurs in advanced phase of the servitization process at the same time that the new business processes and resources are detailed during the development phase. This is another opportunity to further exploring innovation of PSS business models as indicated by Vasantha et al. (2012, p.26).

3.1.7 PSS architecture

In new product development process, one of the deliverables of the design phase is the product architecture (ULRICH; EPPINGER, 2012, p. 24). The architecture is used to translate the product concept into a scheme for enabling the complete development and launching of the product. It helps to identify main elements of the product and divide the overall development work into smaller pieces that can be carried by different specialists or groups. Analogously, the concept of architecture applies for PSS as well.

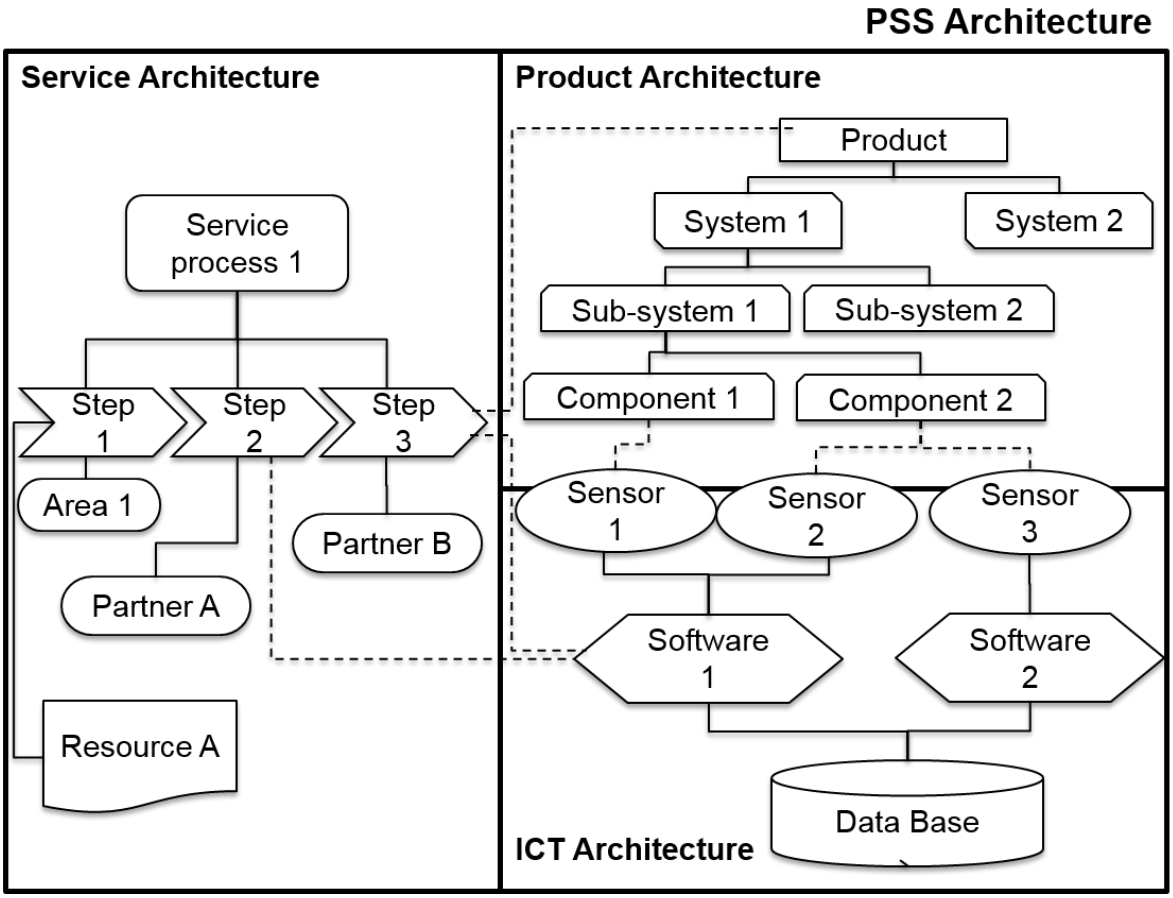
The architecture of a PSS is a scheme in which the functions of the system are allocated into elements of the system (KIMITA; SHIMOMURA, 2014, p. 346). The elements of the PSS system encompass not only physical products, but also nonphysical products (such as human resources, organizations, and the ICT system) that are associated to the services' provision and the ICT integration (KIMITA; SHIMOMURA, 2014, p. 346). Accordingly, the PSS architecture could be represented by the integration of the architectures of the system's individual elements, which consists of the product architecture, service architecture, and ICT architecture, as illustrated in Figure 14.

Since definitions for all of those individual architectures were not found in PSS literature, the specific disciplines related to each architecture were investigated. Each of those architectures are explained respectively in new product development, new service development, and IT disciplines as follows:

- Product architecture: the scheme that identifies the functions of the product, organizes them into major physical elements of the product, and determines how the elements interact (ULRICH; EPPINGER, 2012, p. 185).
- ICT architecture: the arrangement that identifies the applications (such as software) and the technology (such as computer systems, telecommunication networks, databases) of the PSS system, and determines how they relate with the product and service elements (BUCKL et al., 2012).
- Service architecture: the arrangement that identifies the overall service-delivery *processes* and relates them to *people*, *facilitating goods*, and *supporting facility* requirements (TATIKONDA; ZEITHAML, 2002, p. 215). The *processes* are represented by the execution steps for delivering the service. The *people* involves who will perform each execution step for providing the service, which

in the case of PSS may be internal employees or external partners, and what skills and training are required to do that. The *facilitating goods,* which may be interpreted as material resources, involves determining what consumable goods are required for each step and how are they sourced. The *supporting facilities* involve defining required assets, such as furniture or information technology systems (TATIKONDA; ZEITHAML, 2002, p. 215).

Figure 14 - PSS architecture according to Kimita and Shimomura (2014)



SOURCE: created by the author.

From the service architecture definition, it is possible to conclude that the service's concept is translated into processes. That is a consequence of the intangible nature of services that unlike products cannot be represented through sketches of physical pieces, being represented as a sequence of actions (JOHNE; STOREY, 1998, p. 188). However, other types of processes besides those strictly related to service delivery are also necessary for the provision and operation of a PSS. Specially in the case of servitization, when the company already has a set of processes and need to adapt them to the PSS requirements, identifying and understanding those other processes is

also necessary for the PSS architecture. Therefore, the aforementioned representation of the PSS architecture is missing an integration of the PSS core service-delivery processes within the overall business processes of the company. An explanation of the impacts of servitization in the company's overall processes is presented in the following section.

3.1.8 Impacts of servitization on the process dimension[26]

Servitization affects organization's business processes in several aspects. Services require the establishment of new processes oriented to the relationship with customers and to the provision of satisfaction by means of delivering complete final solutions (OLIVA; KALLENBERG, 2003). This demands the adoption of an end-to-end process perspective, which may represent a challenge to manufacturing companies that usually operate with departmental processes focusing on customer requirements rather than satisfaction (MADDERN et al., 2013; OLIVA; KALLENBERG, 2003).

The degree of novelty and changes in business process to provide a PSS depend on the complexity of the services' portfolio. Manufacturing companies that intend to provide a PSS may offer several types of services in different categories. The bigger and more sophisticated the services' portfolio (in terms of differentiation potential) the greater are the transformational effort and, hence, the challenges incurred in the transition (ULAGA; REINARTZ, 2011). Besides establishing new processes, servitization requires process redesign, once existing back-office processes need to be adapted to attend service provision and optimized to guarantee profitability for the PSS. Furthermore, it is important to eliminate unnecessary processes in order to prevent costs associated with delivering services from shrinking business margins (REINARTZ; ULAGA, 2007).

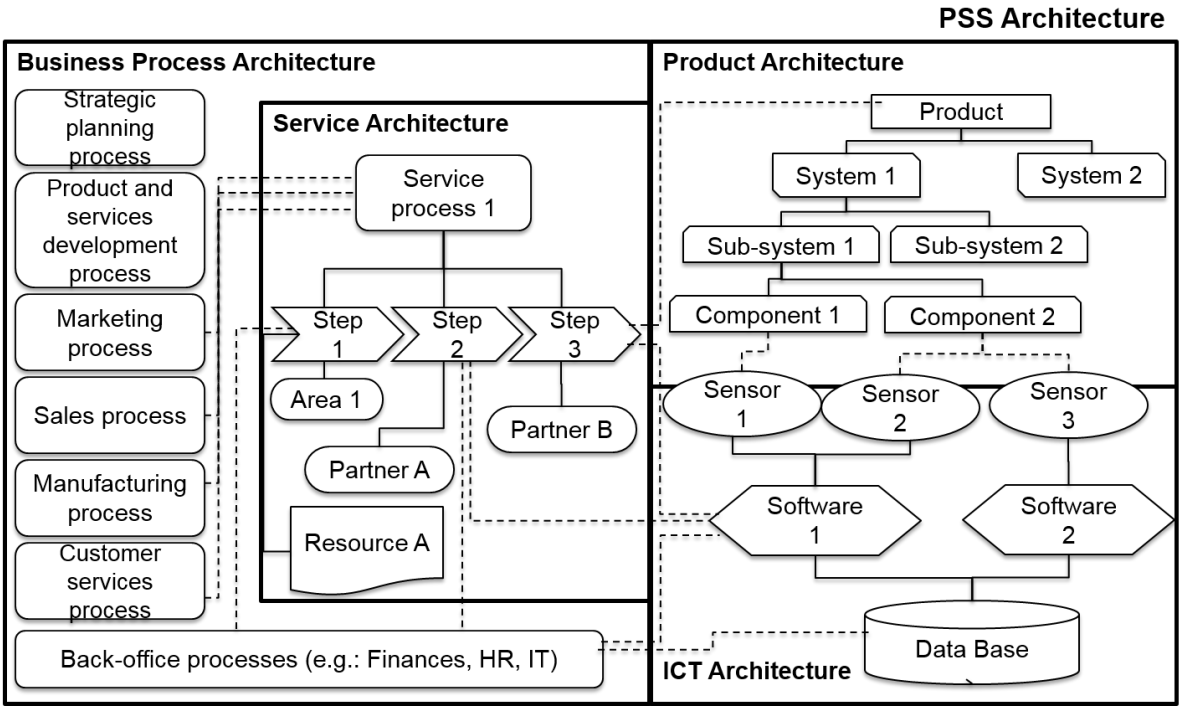
3.1.9 Establishing a connection between Business Process Architecture, Service Architecture, and Organizational Capabilities

All the aforementioned changes in the business process dimension, involve a collection of processes of different natures such as core (indicated as Marketing process, Sales process, Manufacturing process, Customer services process in the left side of Figure 15), management (indicated as Strategic planning process and Product and service development process), and back office processes (indicated in the bottom

[26] Already explained in section 1.1, footnote 2.

left-side of Figure 15). Therefore, it influences not only the organization's service architecture, as indicated in section 3.1.7, but also the complete process architecture and, also the ICT architecture. The service architecture is contained within the process architecture. Thus, a more appropriate illustration of the PSS Architecture is presented in Figure 15.

Figure 15 – New representation of PSS architecture



SOURCE: created by the author.

Hence, the future process architecture for the PSS transition must be clearly defined in light of the current process architecture to enable the organization to plan the transformation of its "capabilities" regarding informational systems structure, people, materials, practices and potential partnerships.

The organizational "capabilities" represent the company's capacity or ability to deploy processes and resources (people and technologies) to affect a desired end (CBOK, 2013; ULAGA; REINARTZ, 2011). The "capabilities" state what the organization can do, and may be represented by "a collection of processes, people and technologies that together provide value toward the achievement of strategic objectives" (CBOK, 2013, p.45). In accordance to that, Bagheri, Kusters, and Trienekens (2014) identified business and IT capabilities necessary for achieving the goals of a PSS value network.

The business capabilities, presented in Table 7, may be deployed in PSS business process, practices, required resources, required people, and potential partnerships.

However, current management text books give insufficient treatment on how to deploy the PSS business capabilities, specially concerning the detailed integration of manufacture and services at the level of the configuration of business process to deliver PSS (BAINES et al., 2009a).

With that background, the best option to start designing PSS business processes in order to achieve a holistic view of the organization could rely on the concept of business process architecture (BPA), which encompasses the service architecture and all the other types of processes of the organization. This approach is in agreement with section 3.1.6, which indicates the potential for applying methodologies from other fields to support PSS design. The next section is dedicated to explain the foundations of BPA.

Table 7 - PSS business capabilities

PSS business capabilities	Meaning
1. Customer understanding	The ability of identifying customers' values and transforming them into requirements in order to offer customized solutions that address customer's process and business needs.
2. Partnership	The ability of developing collaboration and partnership among actors of the PSS value network in order to access complementary capabilities.
3. Trust-based interaction	The ability to establish a relationship of mutual trust and commitment among actors (which may include customers as well).
4. Engagement	The ability to engage all partners to in the value co-creation to deliver the PSS solution.
5. PSS design and delivery	The ability to design and deliver combinations of products and services to individual customers. The services' elements may range from "traditional product-related services to services supporting customer operational processes".
6. Process management	The ability to coordinate and processes to maintain efficiency of the PSS network.
7. Knowledge management	The ability to "capture, transfer, share, and utilize knowledge resources" between actors of the network to deliver integrated PSS solutions. It encompasses infrastructure (technical, cultural, structural) and process (acquisition, conversion, application and protection) aspects.

SOURCE: adapted from Bagheri, Kusters, and Trienekens (2014, p.276).

3.2 Business process architecture

In the following sections BPM fundamental terminology (section 3.2.1), BPA concepts (section 3.2.2), and BPA main classifications (section 3.2.3) are introduced to establish common definitions adopted in this study. Then, BPA methods (section 3.2.4) are explored in order to identify potential insights for supporting the development of the

PSS BPA Development Method. Finally, process modeling foundations including concepts such as business process reference models, modeling languages, and tools are analyzed in section 3.2.5.

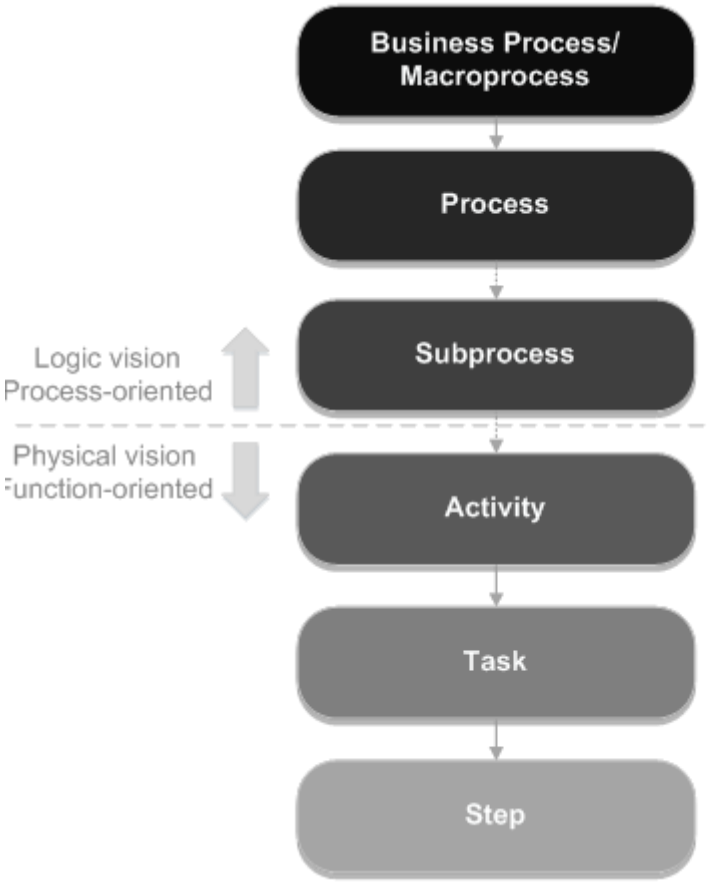
3.2.1 BPM fundamental terminology

Before discussing BPA, it is important to define some fundamental terms from the BPM field: “process” and “business process”. The Guide to the Business Process Management Common Body of Knowledge (CBOK) defines each term as follows (CBOK, 2013):

- “Business process” is defined as “end-to-end work that delivers value to customers” (CBOK, 2013, p.434). “End-to-end” work is a fundamental characteristic for processes in the BPM field, as they require work across functional boundaries enabling the delivery of value to clients (CBOK, 2013, p. 161; MACEDO DE MORAIS et al., 2014).They may also be called “value chain” or “macroprocess” depending on the context. Business processes may be hierarchically decomposed into processes, subprocesses, activities, tasks and steps, as illustrated in Figure 16. Example: “Sell products and services”.
- “Processes” are a set of interconnected activities executed by a human or a computer that transform outputs in inputs to achieve one or more results (CBOK, 2013, p. 160). Example: “Develop and manage sales plans”.
- “Subprocesses” are the immediate decomposition level below processes. They produce a specific part of the end result (CBOK, 2013, p. 161). Example: “Manage leads/opportunities”
- “Activities” are a group of tasks necessary to deliver a definable part of product or service. Example: “Identify customers”, “Identify opportunities”, “Develop sales plan”, “Manage customer sales calls”.
- “Tasks” are a group of “steps or actions taken to perform a specific piece of work” (CBOK, 2013, p.442). In modeling languages, they are commonly referenced as job instructions. Example: for the activity “Manage customer sales calls”, two tasks could be “perform sales calls”, and “close the sale”.
- “Steps” represent the action at an atomic level. Example: for the task “perform sales calls”, steps could be “look up the customer information”, “call the customer”, “present the offer”.

This section supports the terminology section 3.1.6.1 previously presented for PSS design methodologies.

Figure 16 – Business process decomposition structure



SOURCE: adapted from CBOK (2013).

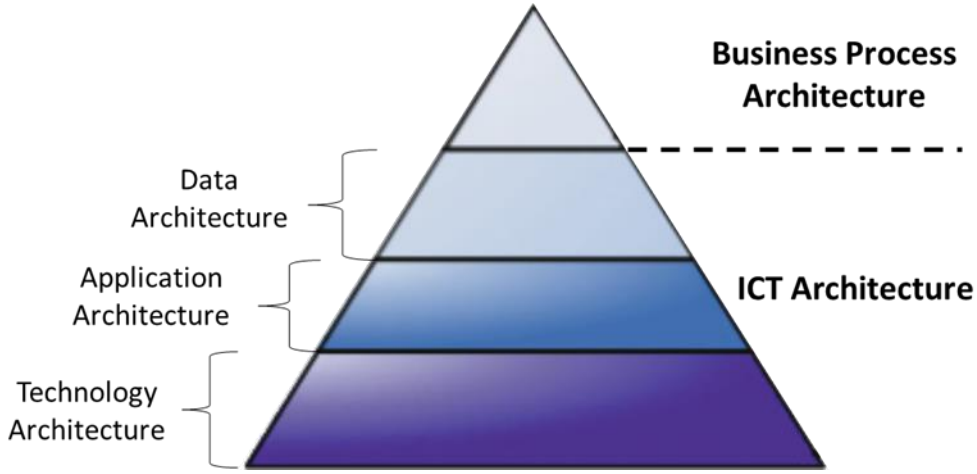
3.2.2 BPA definition and concept

The business process architecture (BPA) describes the relationships and provide guidelines to organize the collection of business processes within an organization. Therefore It can be applied as an instrument for designing and analyzing the set of business process models that represents the complex system of cooperating entities of an entire organization (EID-SABBAGH; WESKE, 2013, p. 208). Summarizing, the BPA determines “how the business is organized to achieve its goals” (HARMON, 2015; p.55).

There seems to exist a confusion between the term “business process architecture” and “enterprise architecture”. Harmon (2015) and Barros and Julio (2011) consider that “enterprise architecture” has the same meaning as “business process architecture” or “business architecture”. Nevertheless, some authors differentiate between both terms

(BURLTON, 2010; RUMMLER; RAMIAS, 2015). “Enterprise architecture” aims at defining and connecting business with information and communication technologies (ICT) elements of an organization (RUMMLER; RAMIAS, 2015, p. 81). Therefore, BPA is interpreted as one component of an enterprise architecture. In fact, it represents the top layer of the enterprise architecture, as illustrated in Figure 17. This study agrees with the differentiation of terms.

Figure 17 - Enterprise architecture model



SOURCE: adapted from Rummler and Ramias (2015, p.82).

BPA is generally represented as a hierarchical model that shows what an organization does in a process perspective at a tactical level (ARMISTEAD; PRITCHARD; MACHIN, 1999). Its creation starts at the strategic top level of organizations and assists operational levels by providing them with context and scope for each individual activity. It works as a connecting layer translating and dissipating the business strategy throughout the organization’s foundations by means of its processes, people, systems and policies. Thus, it enables the organization to work at different abstraction levels and spheres of influence meanwhile it sustains the contents of different levels interconnected and tied (BURLTON, 2010).

3.2.3 BPA typologies

Some typologies have been proposed as a means of classifying the variations of business process architecture. Two of these classifications are reviewed below in order to explore and stablish grounding for the PSS BPA Development Method construction:

Barros and Julio (2011)

Barros and Julio (2011) propose a dual typology based on the BPA origin, which involves professional or academic approaches. Professional BPA approaches are originated from the practical field with the support of single companies, consortiums of companies, industry entities, or government. Academic BPA approaches are originated from universities or academic communities (BARROS; JULIO, 2011, p. 599).

Dijkman, Vanderfeesten, and Reijers (2011)

Dijkman, Vanderfeesten, and Reijers (2011, p.6) create five clusters to classify BPAs based on the way that a BPA is designed. These clusters are:

- Goal-based approach: a goal structure is designed first to guide the definition of business processes that aim at achieving the established goals. The benefit of this approach is that by highlighting the goals, it facilitates the visualization of the importance of each.
- Action-based approach: business actions[27] are designed first. Then, the business processes may be derived from the set of business actions due to their similarity in structure.
- Object-based approach: a business object[28] model is designed first to guide the subsequent design of business processes. This is performed by studying the business objects and their inter-relations in the organization.
- Function-based approach: a function hierarchy of an organization is designed first by decomposition. Then, business processes related to each business function are defined. This procedure may be simpler to apply, because functions (represent what the organization does) are easier to identify than for example business actions (represents how the organization achieves what it does) (DIJKMAN; VANDERFEESTEN; REIJERS, 2011). However, this type of approach contradicts the end-to-end perspective of processes, and may hinder the propagation of the business process mindset that is expected to be reflected

[27] Business actions are loops of activity that complete determined work for internal or external customers (DIJKMAN; VANDERFEESTEN; REIJERS, 2011,p.6).
[28] Business object is an entity originated in the software environment that contains properties and characteristics used to represent processes, such as customers or orders. Business objects are the basis of modeling languages (DIJKMAN; VANDERFEESTEN; REIJERS, 2011, p.8).

in a business process architecture (MACEDO DE MORAIS et al., 2014; MADDERN et al., 2013).

- Reference model based approach: designing a BPA from scratch is time-consuming and incur in excessive costs. Therefore, existing BPAs may work as reference model[29] being re-used or adapted to generate new BPAs in different contexts. The majority of reference models present process collections model and not the architecture itself. Thus, generally the BPA results as a by-product of the reference model. The benefits of this approach is that it accelerate the definition of BPA by starting of an existing model and present best practices that lead to better design. Additionally, it is considered the most easy to use, useful and popular approach.

According to Dijkman, Vanderfeesten, and Reijers (2011, p.16), there is no perfect or dominant approach for BPA. Instead, a combination of guidelines of different types of BPA seems to reflect the state-of-the-art being applied in companies. In accordance to that, in relation to the first typology, this work makes no restriction and looks for insights from both industrial and academic approaches. Regarding the second presented typology, this study adopts the “reference model based approach” due to its benefits such as: easier to use, potential to accelerate the BPA creation, and reliability on best practices.

3.2.4 BPA methods[30]

Although there is a lot of emphasis on creating a Business Process Architecture, there is no established agreement on how to do it (AREDES; PÁDUA, 2014; HARMON, 2015). Some BPA methods were proposed in literature. However, they considerably contrast about applied tools and performed activities. Additionally, different levels of abstraction regarding the processes structure were used in those methods, which may hinder the comparison between them.

[29] Reference models “provide best-practice processes, which can be adapted to aid companies in designing and operating their business” (ROSEMANN, 2003, p.595). This concept is explained in details in section 3.2.5.1.

[30] Approaches for BPA development presented by the six authors refer to the terms methodology, method, model, or framework without clear distinction between them. Those terms should be interpreted in this study as the definitions presented in section 3.1.6.1. This section considers that all presented approaches can be referred to as methods, which consists of systematic procedures using a sequence of steps to complete activities with the support of one or more tools (EDER et al., 2012; PMI, 2013).

.

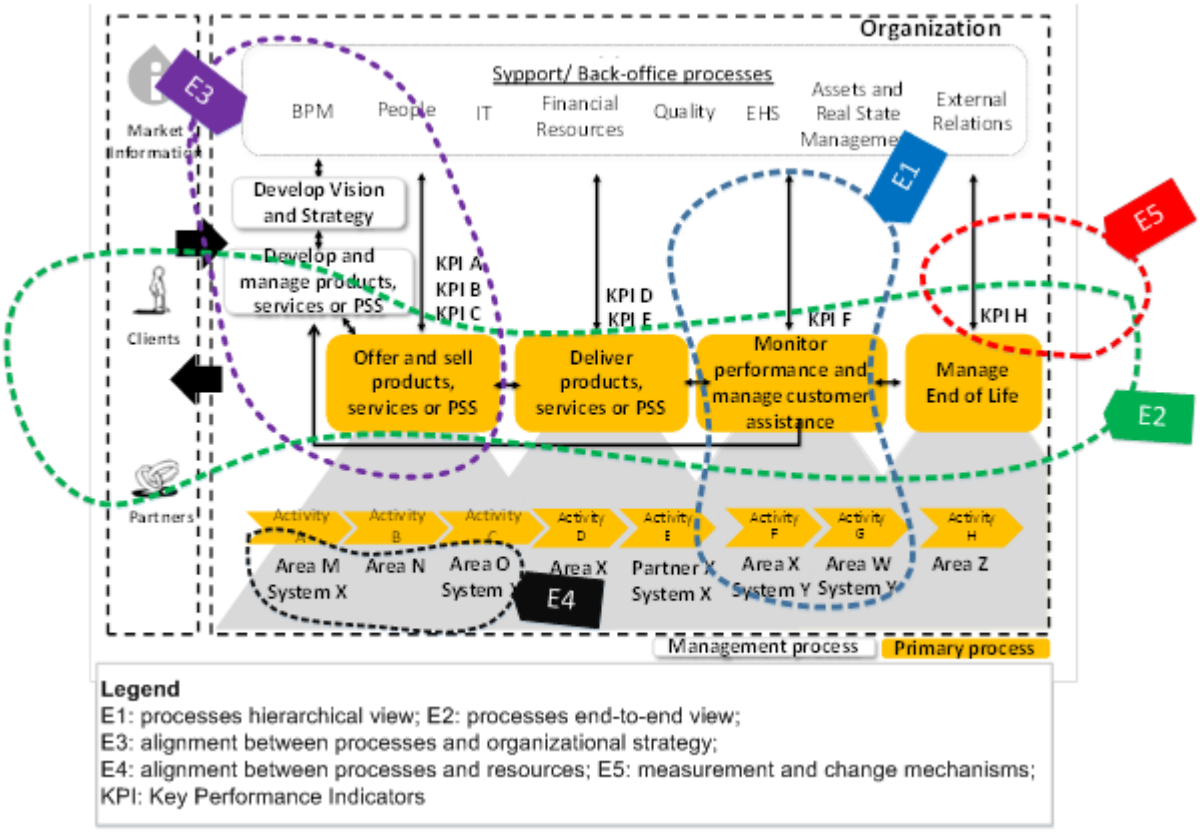
Recent researches (AREDES; PÁDUA, 2014; DIJKMAN; VANDERFEESTEN; REIJERS, 2011) have tried to unify the body of knowledge of BPA. Aredes and Padua (2014, p.246) reviewed BPA literature and by analyzing more than 82 scientific works they propose five critical elements of a BPA, which are:

- Processes hierarchical view (E1): it consists of a model comprising core[31], support[32] and management[33] processes that are structured through hierarchical levels. Depending on the required level of detail, it may contain the detailing of processes into lower levels such as subprocesses, activities, and tasks. Top levels usually describe what the organization does while lower levels describe how the organization does it. The author originally applied the term “vision” instead of “view”. However, “vision” may generate confusion and sound as a high level representation of business processes. This perception has been contradicted by some authors that defend that business process architecture goes beyond a list of main first level processes, including also processes’ hierarchical decomposition. Therefore, the word vision was replaced by the word “view” to avoid misinterpretations.
- Processes end-to-end view (E2): it involves horizontal or cross-functional relationships between processes in different hierarchical levels in order to guarantee the client’s satisfaction from the first contact until the value delivery.
- Alignment between processes and organizational strategy (E3): it unfolds the company’s strategic objectives related to satisfying stakeholders and customers into individual processes.
- Alignment between processes and resources (IT and people) (E4): it denotes the company’s resources necessary to support business processes. The most commented resources in literature are people and IT systems.
- Measurement and change mechanisms (E5): it defines performance indicators for the processes in order to measure and control the achievement of the company’s strategy and goals towards change.

An illustration of those elements is depicted in Figure 18.

[31] Already explained in section 1.1, footnote 8.
[32] Support processes “do not directly deliver value to customers” (CBOK, 2013, p.60). Instead they offer support to core processes (CBOK, 2013).
[33] Management processes aim at measuring, monitoring, controlling and managing activities to ensure that business achieves established results and goals (CBOK, 2013).

Figure 18 – BPA critical success elements



SOURCE: created by the author.

Taking those five critical elements of BPA as reference, Aredes (2013) analyzed 8 different BPA methods and concluded that none of them was completely adherent to all five elements. Nevertheless, the performed analysis presents some weaknesses that could be improved. Aredes (2013) evaluates the methods using notes that varies from 0 to 5; nevertheless, he only defines the meaning of a note 0 or 5. Thus, a first improvement consists of clearly defining the meaning of each note in the scale before performing the analysis. Another improvement, consists of including one new BPA method from Malinova, Leopold and Mendling (MALINOVA; LEOPOLD; MENDLING, 2015), which emerged in literature after the publication of Aredes (2013), in the analysis and substituting other two methods (BURLTON, 2010; RUMMLER; RAMIAS, 2010) by their latest versions (BURLTON, 2015; RUMMLER; RAMIAS, 2015).

In the following topics, some BPA methods proposed in literature are reviewed already considering the aforementioned improvements. Three methods (AITKEN; STEPHENSON; BRINKWORTH, 2010; DUMAS et al., 2013; OULD, 1997) that showed low adherence to the five critical elements in Aredes (2013) were not

considered in this analysis. At the end, Table 8 compares all six analyzed methods in light of a “new note scale” in order to support the selection of one BPA method to be taken as reference in the proposition of the PSS BPA Development Method.

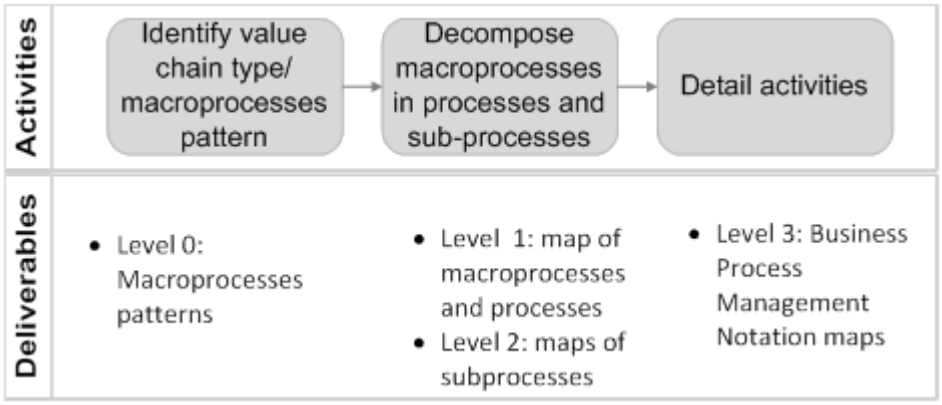
3.2.4.1 BPA 1: Barros and Julio (2011)

Barros and Julio (2011) proposed a BPA method that considers that the BPA of any organization can be modeled by means of four general business process patterns, called macroprocesses, as described below. These structures combined generate several typical architecture patterns that can be used to perform architectural design in particular cases.

- Macroprocess 1 – represents the value chain and encompasses process responsible for providing physical goods and services to the customers (including requests’ formulation, production and satisfaction of customer’s requests).
- Macroprocess 2 – includes processes for the development of new capabilities such as new products, services or business models development; infrastructure development; new processes development.
- Macroprocess 3 – represents the Business Planning and includes processes related to the definition of the organization’s strategy.
- Macroprocess 4 – encompasses support processes for the operation of the other three macroprocesses (such as Human Resources management, Finance management, and so on).

The method includes three main activities as indicated in Figure 19. This method’s main focus is on the relationships and interdependencies between processes at different level of abstraction (E1 - Processes hierarchical view), which includes also processes in distinct business units inside one organization (BARROS; JULIO, 2011). Nevertheless, it presents gaps as it partially covers or lacks four of the elements pointed out by Aredes and Padua (2014) as critical for the BPA, such as Processes end-to-end view (E2), Alignment between processes and organizational strategy (E3), Alignment between processes and resources (IT and people) (E4), and Measurement and Change Mechanisms (E5).

Figure 19 - Barros and Julio (2011) BPA method



SOURCE: created by the author.

3.2.4.2 BPA 2: Morrison et al. (2012)

Morrison et al (2012) propose a method that focus on aligning the organization's strategies and the business processes (E3), which they call strategic alignment. As it seems to be oriented to information technology field, the alignment is established with the support of two modeling languages: Strategy Modeling Language (SML) and Business Process Management Notation (BPMN). The SML is composed by three modeling elements:

- Functional Goal: desired outcomes of an organization;
- Plan: a set of goals realized in a specific sequence;
- Optimization Objective: preferences for achieving the strategic outcomes.

The main activities of this method are depicted in Figure 20.

Figure 20 - Morrison et al. (2012) method

SOURCE: created by the author.

Nevertheless, this method is not comprehensive as it lacks support for determining four elements pointed out by Aredes and Padua (2014) as critical for the BPA: Processes hierarchical view (E1), Process end-to-end view (E2), Alignment between

processes and resources (IT and people) (E4), and Measurement and Change Mechanisms (E5).

3.2.4.3 BPA 3: Sabbagh, Dijkman and Weske (2012)

This paper has a technical language and seems to be oriented to information technology field. The authors propose a method for representing the business process architecture, whose focus is on defining processes' end-to-end interdependences (E2 - Processes end-to-end view), which may be classified in two patterns: trigger or information flow (SABBAGH; DIJKMAN; WESKE, 2012). The method consists of three main activities as depicted in Figure 21.

Figure 21 - Sabbagh, Dijkman and Weske (2012) BPA method

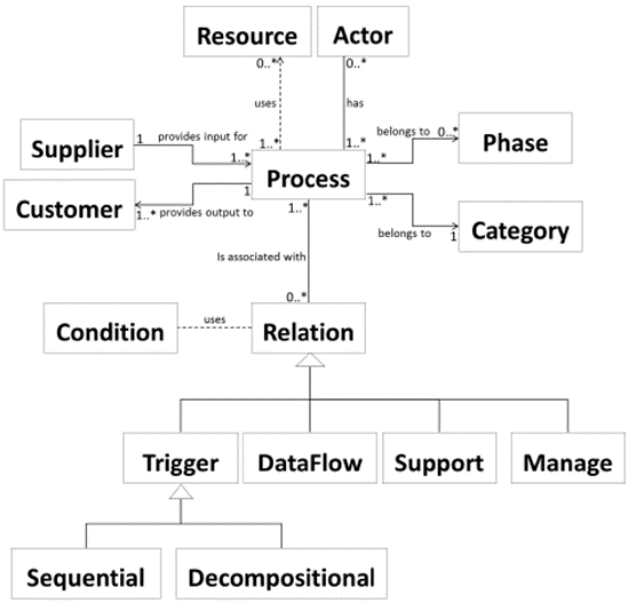
SOURCE: created by the author.

One gap of this method is that it does not support the identification of necessary business processes, which is fundamental to occur previously to the definition of the relationship patterns. Furthermore, this method is not comprehensive as it lacks four elements pointed out by Aredes and Padua (2014) as critical for the BPA: Processes Hierarchical View (E1), Alignment between processes and organizational strategy (E3), Alignment between processes and resources (IT and people) (E4), and Measurement and Change Mechanisms (E5).

3.2.4.4 BPA 4: Malinova, Leopold and Mendling (2015)

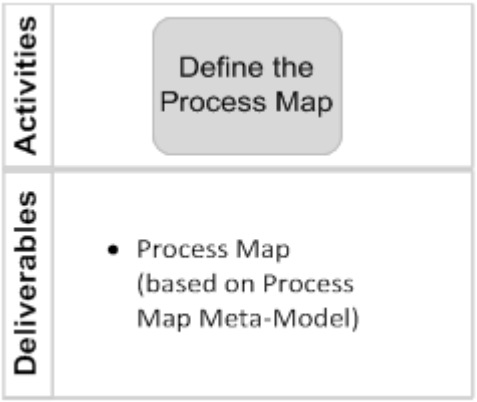
According to these authors, the top-level or most abstract level of a process architecture is called process map (MALINOVA; LEOPOLD; MENDLING, 2015). In this work, the authors conducted a research with 67 process maps (coming from BPM books, and practical cases from companies or case studies) and defined a Process Map Meta-Model to support the definition of a BPA as depicted in Figure 22. Therefore, these authors only approaches one activity to define the BPA: Define the Process Map (starting with the Process Map Meta-Model), as described in Figure 23.

Figure 22 - Process map meta model



SOURCE: Malinova, Leopold and Mendling (2015).

Figure 23 - Malinova, Leopold and Mendling (2015) method



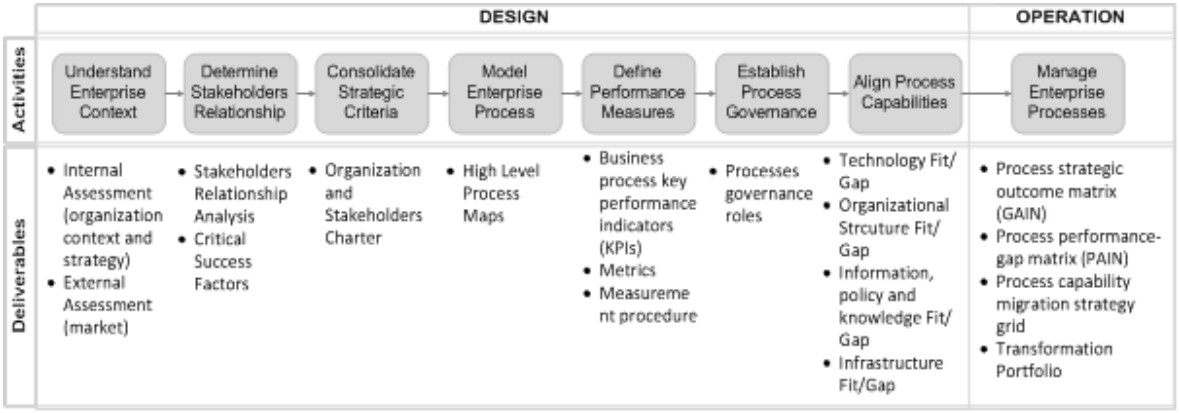
SOURCE: created by the author.

The main contribution of this work was proposing a standard language for the top-level of a BPA. It focus on defining the top-level processes as well as the aspects to support its execution, such as interrelationships (E2 - Processes End-to-End View), category (E1 - Processes Hierarchical View), resources and actors (E4 - Alignment between processes and resources). However, it cannot be considered a complete method for defining a BPA since it lacks some of the elements pointed out by Aredes and Padua (2014) as critical for the BPA, such as Alignment between processes and organizational strategy (E3), and Measurement and Change Mechanisms (E5).

3.2.4.5 BPA 5: Burlton (2015)

Burtlton (2015) proposes a method called BPTrends Business Process Architecture. This version is an improvement of the method previously presented in Burlton (2010). The method is composed by eight main activities as depicted in Figure 24.

Figure 24 – BPTrends Business Process Architecture method



SOURCE: adapted from Burlton (2015).

The main focus of this BPA method is aligning the organization's strategic orientation with its business processes (BURLTON, 2015). Furthermore, as shown in Figure 24, BPTrends Business Process Architecture method's activities are able to deliver all five critical elements of a BPA according to Aredes and Padua (2014). Nevertheless, not all activities are described in sufficient detail to support their execution. There is a need of better describing some activities by indicating methods or tools to support their execution (such as how to define a Performance System or how to allocate Resources).

3.2.4.6 BPA 6: Rummler and Ramias (2015)

Rummler and Ramias (2015) proposes a method for defining what they call a Value Creation Architecture (VCA), which encompasses the Business Architecture, the Management System Architecture, the Technology Performance Architecture, and the Human Performance Architecture.

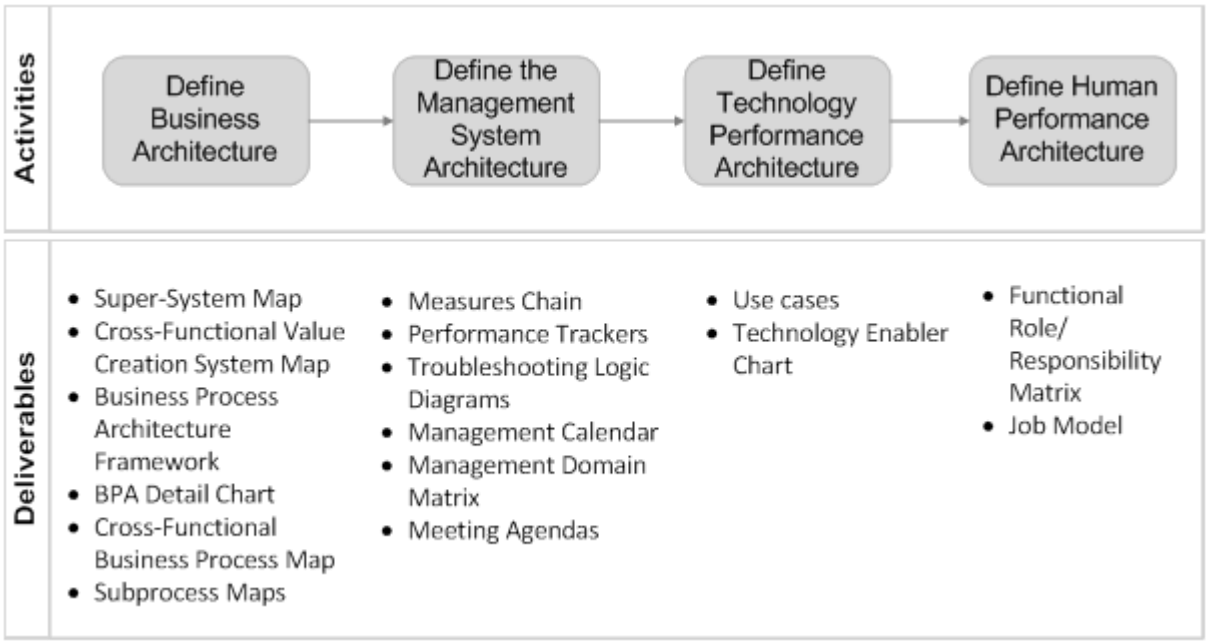
The Business Architecture is derived from a structure called Value Creation Hierarchy (VCH), which is composed of five levels:

1. Enterprise Level
2. Value Creation Level
3. Processing Sub-Systems Level

4. Process Level
5. Subprocess/Task/Subtask Level

The activities and deliverables comprised in Rummler and Ramais (2015) method are depicted in Figure 25.

Figure 25 – Value Chain Architecture method



SOURCE: created by the author.

The VCA method encompasses all five critical elements of a BPA according to Aredes and Padua (2014), however the activities to obtain some elements (such as Processes End-to-End View (E2), Processes Hierarchical View (E1), and Alignment between Processes and Strategy (E3)) require further detailing, such as the indication of methods or tools to support their execution.

3.2.4.7 Comparison of BPA methods

The objective of this section is selecting one BPA method to be taken as reference in the proposition of the PSS BPA Method. As depicted in Table 8 there are two BPA methods with 70% of adherence to the BPA critical elements: the ones from Burlton (2015) (BPA 5) and Rummler and Ramias (2015) (BPA 6).

This work considers the BPTrends Business Process Architecture method from Burlton (2015) as the reference for the development of the PSS BPA Development Method due to two main reasons:

- It is a professional and reference model based approach, which may accelerate the definition of the BPA;
- It focus on aligning strategy with business processes, which is fundamental for the context of servitization, where the company changes elements of its strategy.

Table 8 - Comparison of BPA methods

Method[1]	Type of BPA	BPA critical elements[2]					
		E1	E2	E3	E4	E5	Result[3]
BPA 1	• Academic/Professional • Reference model based approach	2	1	0	0	0	**3**
BPA 2	• Academic	0	0	2	0	0	**2**
BPA 3	• Academic	1	2	0	2	0	**5**
BPA 4	• Academic	2	1	0	0	0	**3**
BPA 5	• Professional • Reference model based approach	2	1	2	1	1	**7**
BPA 6	• Academic	1	1	1	2	2	**7**

[1] The six methods are: BPA 1- Barros and Julio (2011); BPA 2 - Morrison et al. (2012); BPA 3 - Sabbagh, Dijkman and Weske (2012); BPA 4 - Malinova, Leopold and Mendling (2015); BPA 5 – Burlton (2015); BPA 6 – Rummler and Ramias (2015).

[2] The five critical elements are: Processes hierarchical view (E1), Process end-to-end view (E2), Alignment between processes and organizational strategy (E3), Alignment between processes and resources (IT and people) (E4), and Measurement and change mechanisms (E5).

[3] The adherence scale means: 0 - Method does not consider the critical element; 1 – Method considers the critical element but does not present clear tools to support its definition; 2 - Method presents tools to determine the critical element. The highest possible sum in the result column is 10. The result column should be interpreted as a fraction “result/10” that can be converted in percentage. Hence, the higher the sum in the column results, the more adherent is the method with the critical elements of a BPA.

SOURCE: adapted from Aredes and Padua (2014).

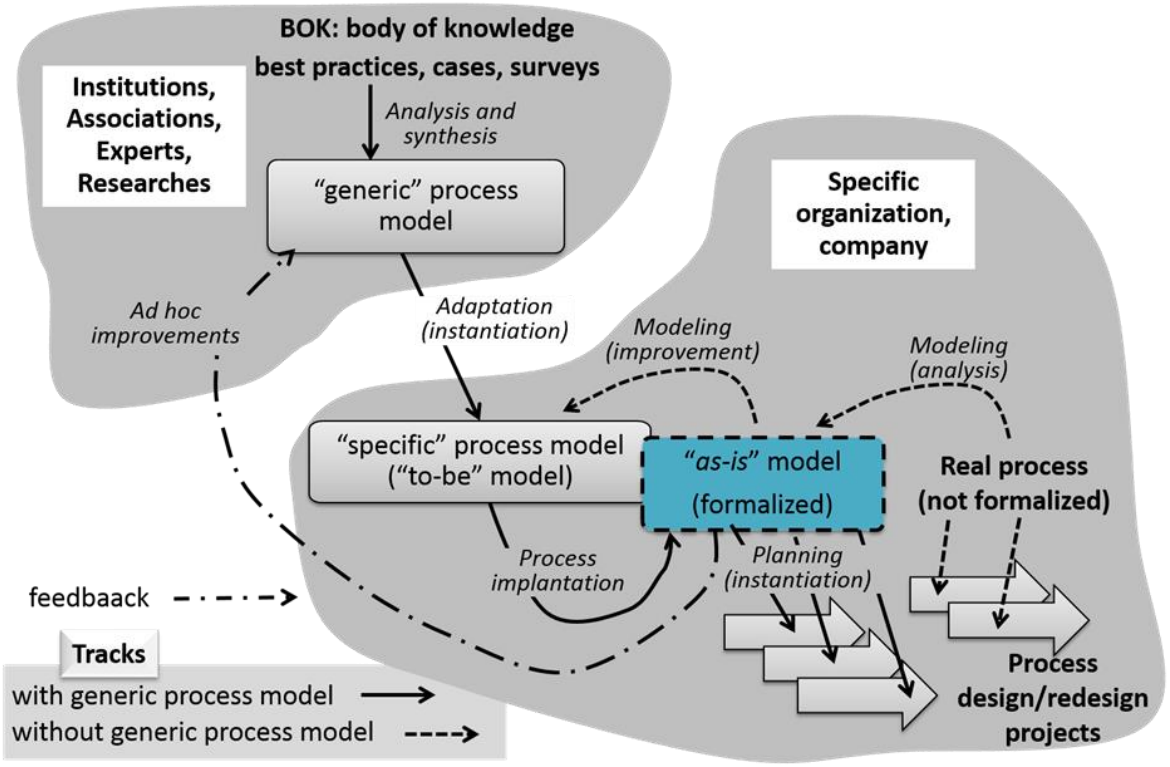
3.2.5 Process modeling foundations

This section reviews three fundamental concepts for supporting the development of business process architecture: business process reference models (section 3.2.5.1), business process modeling languages (section 3.2.5.2) and business process modeling tools (section 3.2.5.3). The connections of the aforementioned concepts with the area of PSS are also analyzed.

3.2.5.1 Business process reference models

As already mentioned in section 3.2.3, business process reference models can support the identification of the collection of processes of an organization in order to accelerate the BPA definition. Business process reference models (or generic process models) are “process descriptions (model world) which can provide the basis for real world process instances” (HOUY; FETTKE; LOOS, 2010, p.160). They represent best practice processes. The central idea of such models is to enable organizations to use available experience and market best practices when composing their own BPA instead of trying to reinvent what already exists (CBOK, 2013; ROSEMANN, 2003).They can also be called “generic reference models”, “model patterns”, “business process blueprints” (FETTKE; LOOS; ZWICKER, 2005), “reference process models” (ROSEMANN, 2003) or “business process frameworks” (HARMON, 2015). The adaptation of generic process models for a specific organizational context generating one specific process model is called instantiation, as illustrated in Figure 26.

Figure 26 - Relationship between generic and specific process models



SOURCE: adapted from Amigo (2013, p. 213).

Nevertheless, there exist some confusion in literature and practical field, since the terms “business process reference model” or “business process framework” have been

used with different meanings in different contexts (FETTKE; LOOS, 2006). As a way to clarify the terminology and avoid inconsistencies, Houy, Fettke and Loos (2015) classify business process frameworks in three categories as described in Table 9.

Table 9 - Business process framework categories

Categories	Definition	Examples
1. Methodical business process engineering approaches	Support the development of process-oriented Information Systems, guiding the definition of the process models, the IS structure, the procedure models, the software implementation for enabling process management.	• Architecture of Integrated Information Systems (ARIS) • Zachman Framework Computer Integrated Manufacturing Open System Architecture (CIMOSA)
2. Technical infrastructures for process integration and process model interchange	Technical infrastructure for process integration and process model interchanges through workflows.	• XML Process Definition Language (XPDL) • ebXML Business Process (ebBP) OASIS standard
3. Business process blueprints or reference process models	Process descriptions that can provide basis for the real world, acting as prescriptions. Representations of best practice processes that may be used to characterize a structure of work in an organizational system.	• Supply Chain Operations Reference Model (SCOR) • Process Classification Framework (PCF) • Information Technology Infrastructure Library (ITIL)

SOURCE: adapted from Houy, Fettke and Loos (2015).

Category 1 and 2 are related to Systems' Architecture, and so are out of the scope of this research. Category 3 is the focus of this work, since it is the one consistent with the perspective of business process architecture. Therefore, every time that the term "business process reference model" appears in this work in the following topics, the reader should interpret it as "business process blueprints" or "reference process models".

There are numerous business process reference models in literature with universal or specific applicability for different industry segments, areas of knowledge, or technologies (FETTKE; LOOS; ZWICKER, 2005). Existing models are not uniform in respect to their structure, and their elements - which can include processes, practices, and performance indicators - vary considerably. The most cited are: the Supply Chain Operations Reference-Model (SCOR) that focus on supply chain operations and was developed by APICS' Supply Chain Council, the Process Classification Framework

(PCF) developed by The American Productivity and Quality Center (APQC) and applicable to multiple industry sector (generic domain); the IT Infrastructure Library (ITIL) oriented to IT departments or business, and the Value Reference Model (VRM) (BARROS; JULIO, 2011; BURLTON, 2010; CBOK, 2013; DUMAS et al., 2013; HARMON, 2015; MALINOVA; LEOPOLD; MENDLING, 2015).

One important characteristic of business process reference models is that they work as guides to support a company in representing its own reality by designing a specific process model for their context. Hence, generic business process reference models must be adapted to the requirements of each enterprise and should not be simply embedded as a copy (CBOK, 2013). Accordingly, elements of different business process reference models can be combined to compose a new solution (FETTKE; LOOS; ZWICKER, 2005; ROSEMANN, 2003), which is, in fact, the main source of business process reference model innovation (GEROSA; TAISCH, 2009). Combining reference models requires a process of selecting relevant parts of one model and further extending the model elements in order to specialize it (ROSEMANN, 2003).

The development of a BPA for the operation of a PSS in the MOL and EOL phases may benefit from the combination of business process reference models. Some researches have applied this approach before. The first example is Becker, Beverungen, and Knackstedt (2008) that combine reference models from manufacturing and service fields - Y-CIM (Computer Integrated Manufacturing) model with the Service-Y Model - in order to design the product-service process model for truck fleet offering.

Gerosa and Taisch (2009) integrate the SCOR reference model with industrial services' elements in order to incorporate service suppliers' activities in the logistics value chain. A limitation of that work is that not all types of services concerning general PSS concepts, such as training and end of life solutions, were considered in their reference process model.

Aurich, Fuchs, and Wagenknecht (2006) propose the construction of a business process reference model to support the design and operation of PSS by combining elements of generic reference models from manufacturing and services domains. Their approach is based on the process modularization[34] concept, which involves the

[34] Process modularization is obtained by decomposing processes into "modular subprocesses" or "processes modules". A process module can be described as a "black box" that promotes a change in

creation of a catalogue of elementary process building blocks[35] (from manufacturing and service domains) that can be selected according to each enterprise context. Nevertheless, they did not empirically applied the proposed approach for structuring processes for the operation or realization of services in the PSS, which is a limitation.

Finally, Curiazzi et al. (2016) present a case study in which a standard process model for delivering product-oriented services was created in a company from the energy solutions' sector (ABB) by combining the Customer Chain Operations Reference model (CCOR) -which is a part of the SCOR structure that focus on sales operations and customer support business processes - with ABB's specific service processes framework. Nevertheless, the study is still under development and until the moment it has been empirically applied only for one type of process (field service). Another limitation is the absence of a holistic process view that enables the identification of interdependences between different processes of the organization, especially the interfaces between product delivery and services delivery processes.

Despite the aforementioned benefits of reference process models, and as described in some limitations of the previous referenced researches, companies may face some difficulties such as:

1. Limited access to reference models since they are spread in academic literature and normative documents, or have restricted access for members of private consortium of companies;
2. Companies may be confused and lack the ability to choose one model within the vast bulk of options that are not easy to compare due to their different structure and level of abstraction.

Trying to minimize those challenges, a directory with existing process reference models called *Reference Modeling Catalogue*[36] is provided by the Institute for Information Systems (IWi) at the DFKI and Saarland University, Saarbrücken. This catalogue was a result of a research project funded by the German Research Foundation (DFG) from 2004 to 2006 (HOUY; FETTKE; LOOS, 2015). Nevertheless, this catalogue present some limitations. First, it seems to be out of date, once relevant

state, transforming ingoing states in outgoing states (AURICH; FUCHS; WAGENKNECHT, 2006, p.1488).
[35] Similar to "process module".
[36] http://rmk.iwi.uni-sb.de/

models, such as the PCF from the APQC, are not comprised in it. Secondly, it does not give direct access to all original models. Thirdly, several catalogued models are available only in German language. Therefore, there is a need for consolidating an updated library of available reference models in English language to support companies on developing the BPA (AURICH; FUCHS; WAGENKNECHT, 2006, p.1490).

3.2.5.2 Business process modeling languages (BPMLs)

Specific process models, which are the instantiated business process reference models (or generic process models) as explained in section 3.2.5.1, are generally represented in formal description notations that aim at establishing a pattern or common “language” for communication with the model’s users. These description notations may be divided in two categories: written executable computer codes (IT oriented) or graphical illustrations of process concepts (business oriented), whereby the latest are frequently called Business Process Modeling Languages (BPMLs) (IVANOV; REUL, 2007, p.1). Since the BPML illustrates the business perspective of the process models, this concept is closely related to the representation of a BPA, and therefore it is the focus of this section.

A clear communication is fundamental when modeling business process. The process models represented by the BPMLs need to be comprehended by all users (REIJERS; MENDLING; RECKER, 2015, 169). As a consequence, different types of information shall be integrated into the process model to adequately describe the business process according to the users’ requirements, such as knowing “what should be done”, “who should do it”, and “when, where and how should it be done” (LIST; KORHERR, 2006, 1532). Those types of information represent the different aspects of processes (LIST; KORHERR, 2006, p.1533), which may also be called as process “views”. Some examples of processes aspects or views are (LIST; KORHERR, 2006, 1533):

- Functional aspect: represents “what should be done” in terms of processes elements. The processes elements considered in this study are *subprocess, activities, tasks*, and *steps*, as explained in section 3.2.1.
- Organizational aspect: indicates by whom and where the process elements are executed. This aspect may be represented by an *organizational unit*, a *role*, a *specific person (human)*, or an *automatic resource (software)*. An *organizational unit* represents a group of *people* and may be internal (like a certain department

or functional area within the organization) or external (a supplier, or customer). A *role* is a function that a *person* performs in the company. This study's scope does not include the detailing of *specific person*. Hence, in the subsequent sections, the following terms should be interpreted as follows:

  - *People* (which is the terminology adopted after the BPA critical elements described in section 3.2.4): an *organizational unit* (for the level of processes and subprocesses) or a *role* (for the level of activities).
  - *IT systems* (which is the terminology adopted after the BPA critical elements described in section 3.2.4): a *software* or a *module of a software*.

- Behavioral aspect: designates the sequencing of process elements. It may be represented by controls such as: *AND Split, AND Join, XOR Split*, *XOR Join*.
- Informational aspect: represents the informational entities generated or manipulated by processes. They include data, artifacts, products, and objects. In modeling languages they may be represented by an *even*t (trigger activities) or a *resource* (produced or consumed by an atomic activity).

Besides those, other types of process aspects are also possible depending on the user's requirements and the BPML applied. BPMLs were developed in different research domains, such as process engineering (which may be oriented to a marketing or manufacturing perspective), and software engineering (or Information Systems) (BECKER; BEVERUNGEN; KNACKSTEDT, 2008, p.6; LIST; KORHERR, 2006, p.1532). Table 10 and Table 11 present some examples of well-stablished BPMLs in research and industries, according to Becker, Beverungen, and Knackstedt (2008), List and Korherr (2006), and Ivanov and Reul (2007).

A characteristic of the BPMLs presented in Table 11 is that they focus on representing processes at a detailed-level by modeling the *activities* or even the atomic level of the action, which results in *tasks* and *steps*. For modeling the levels of *process* and *subprocesses*, other types of modeling languages are more adequate (IVANOV; REUL, 2007, p.1), such as the Value-added chain (VAC) or the SIPOC, as explained in Table 10.

Table 10 - Business process modeling languages at conceptual levels (process and subprocess)

BPML	Description
Value-added chain (VAC)[1]	They may be interpreted as conceptual models. Main process aspects in VAC are: - *functions*: directly add value to the company; can be arranged *sequentially* and in *hierarchical structure* (such as *processes* being deployed in *subprocesses*); - links between *functions* with *organizational units* and *information objects*.
SIPOC[2]	Used for modeling processes at high level. SIPOC describes *process* in terms of Suppliers, Inputs, Process, Outputs, and Customers. Suppliers and Customers represent *roles*.

SOURCE: adapted from [1]Ivanov and Reul (2007) and [2] Harmon (2015).

According to Becker, Beverungen, and Knackstedt (2008), current available BPMLs (such as the ones presented in Table 11) are not adequate for representing PSS process model, mainly because they are specifically oriented either to service provision (marketing perspective), product provision (manufacturing perspective) or systems information. None of the BPMLs comprise all aspects required for operating an integrated bundle of products and services (PSS) such as: attributes of the product, the service process, resources used during the service process, and information about the integration of product and service.

Hence, the authors suggest integrating complementary modeling languages from different domains, such as the EPC and the Service Blueprinting, for properly representing a PSS. They propose an adapted BPML (Figure 27) by adding the lines of the Service Blueprinting (which differentiates “support activities”, “front-office activities”, and “customer activities”) in the EPC notation (where the rectangles with rounded corners represent *activities*, the hexagons represent *events*, and the circles represent *controls or* connections of splitting and joint points) in order to highlight the interactions with the customer.

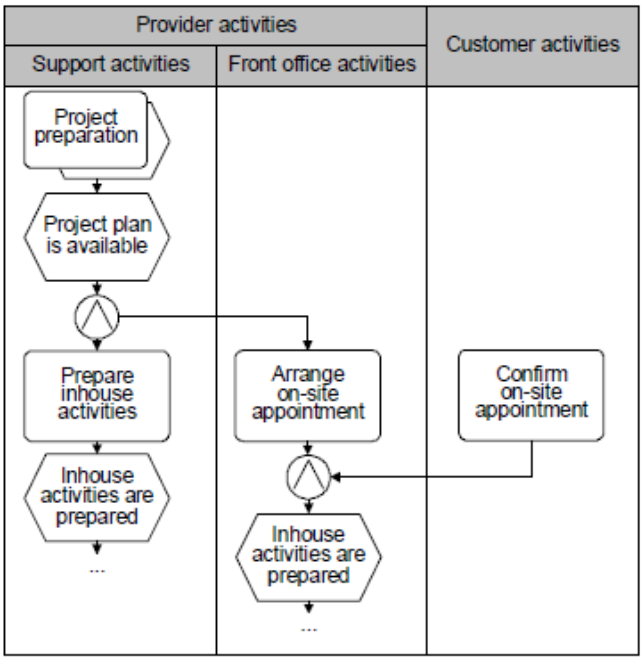
Table 11 - Business process modeling languages at detailed levels (activities, tasks, steps)

Domain	BPML[1]	Description
Information systems	Event Driven Process Chain (EPC)	Designed for being easily comprehended and used by business-oriented users in the ARIS platform (for more information see next section). The basic process aspects are: - functions: model the activities of a business process; - events: created by executing functions or by actors outside of the model.
Information systems	Business Process Modelling Notation (BPMN)	Designed for modeling business processes and their transformation in an execution language called Business Process Modeling Language (BPML). The main aspects are actions and swimlanes (representing roles).
Information systems	UML 2.0 Activity Diagram (AD)	Designed for modeling business processes and flows in software. Similarly, to the BPMN, the main aspects of AD are actions and swimlanes.
Information systems	Integrated DEFinition Method 3 (IDEF3)	Designed for modeling business processes and systems. Contains the model of the process sequence and the model of objects and their changing states.
Information systems	Petri Net	Designed for modeling, analysis and simulation of dynamics systems, it is used for modeling workflows. Contains two types of process aspects: - places: possible states of the system; - transitions: events or actions that cause the change of state.
Information systems	Role Activity Diagram (RAD)	Its originally purpose was modeling coordination, but currently has been applied in business process modeling. The main aspects are roles, their activities and interactions, and external events.
Process engineering/ Marketing	Service Blueprinting	Designed for modeling the interaction activities between service providers with the customer. It differentiates the customer and provider's activities by using lines. Generally two separations are applied: - line of interaction: separates the activities from customer and provider; - line of visibility: separates activities that can be perceived by customer (front-office), from those that cannot (back-office).

[1] Three modeling languages from manufacturing perspective (Emmrich, poDLE, and Business Integration model) described in Becker, Beverungen, and Knackstedt (2010) were not included in this review because their original publication was in German. Furthermore, other two modeling languages were excluded from the analysis due to their decreased relevance in occurrence: the molecular model (BECKER; BEVERUNGEN; KNACKSTEDT, 2010) and the Business Process Definition Metamodel (BPDM) (LIST; KORHERR, 2006).

SOURCE: adapted from Becker, Beverungen, and Knackstedt (2008) and List and Korherr (2006).

Figure 27 - Integration of EPC and Service Blueprinting



SOURCE: Becker, Beverungen, and Knackstedt (2008).

Besides that, it is also possible to extend the aforementioned BPMLs from Table 11, in order to represent other business process “aspects” or “views” for communicating with different users (KORHERR; LIST, 2007, p. 287).

3.2.5.3 Business process modeling tools

A good practice when designing process models is using a process modeling tool (IVANOV; REUL, 2007, p.1; REIJERS; MENDLING; RECKER, 2015, p.169). Reijers, Mendling, and Recker (2015) strongly recommend the use of any dedicated modeling tool instead of using diagramming applications such as Visio or PowerPoint.

A modeling tool may comprise a software and/or other computerized system. It may be applied for planning, analyzing, optimizing and simulating business processes and other business information (IVANOV; REUL, 2007, p.1).

Several modeling tools have been designed and are commercialized by different suppliers. These tools usually allow the use of different BPMLs for modeling processes and its aspects at varying “levels of detail”, and from different “views”. One example is a tool called ARIS Platform of IDS Scheer AG (Saarbruecken, Germany), which has been a market leader. It is usually applied with VAC diagrams for conceptual level and EPC for detailed level (IVANOV; REUL, 2007, p.1).

The selection of an appropriate modeling tool depend on each organizational context. Some requirements of the tool for supporting the selection process are: support of desired BPML, availability of relevant supporting reference process models, adaptability to the organizational context, interfaces to other solutions, access by multiple users, internet access, redundancy, and reports and analysis functionalities (BECKER; KUGELER; ROSEMANN, 2003, p.57).

3.3 Literature review synthesis

This section synthetizes key information from literature review in order to identify potential requirements to guide the development of the PSS BPA Development Method.

Four requirements are generated by synthetizing information from literature review in order to answer the research question presented in section 1.2: How should existing methods from BPM field for defining BPA be applied during the PSS business model development (BOL phase) to support manufacturing companies in defining the business processes for the operation (MOL and EOL phases) of a new PSS?

Those requirements represent the second deliverable of the second stage of this research: *PSS BPA Development Method Requirements (D.2.2),* as described in the methodology section 2.2.2.2. They are explained in details in the following topics.

Requirement 1 – Potential of combining BPA methods and PSS business model design methods

From the PSS perspective, as described in section 3.1.6, there is no consensus in literature about a complete methodology to guide manufacturing companies in transforming their business models to become PSS providers. Existing business model design methods generate simplified and aggregated business dimensions that are at a high level of abstraction and does not help companies solving operational issues, such as “how is the best way to adapt business processes of manufacturing companies to PSS context?”

On the other hand, as described in section 3.2.4, a BPA enables a representation of enough level of detailing in terms of required processes, resources and indicators, to support the execution of a company’s strategy. Therefore, there is an opportunity to combine existing methods from BPM field, such as methods for defining business process architecture, with PSS business model design methods.

Hence, business process architecture concept and methods could be incorporated in the PSS Business Model definition.

Requirement 2 – What are the elements of a BPA

After confirming the potential of combining BPA into the PSS business model development (Requirement 1), it is important to summarize the concept of BPA.

As described in section 3.2.4, it was verified that a business process architecture contains at least five fundamental elements: “processes hierarchical view (E1)”, “processes end-to-end view (E2)”, “alignment between strategy and processes (E3)”, “alignment between processes and resources (E4)”, and “measurement and performance control mechanisms (E5)”.

Therefore, the development of the PSS BPA Development Method should encompass activities to deliver the five fundamental elements of the BPA (E1, E2, E3, E4 and E5).

Requirement 3 – Methods for creating a BPA

After confirming the potential of applying BPA in the PSS field and understanding its critical elements, it is important to identify methods to develop the BPA.

As described in section 3.2.3, it is a good practice to use business process reference models as a means to accelerate the definition of a BPA. In section 3.2.4, six methods for defining a BPA were compared. The method BPTrends Business Process Architecture from Burlton (2015) was identified as reference for the development of the PSS BPA Method due to its adherence to all five BPA elements (Requirement 2) and the use of reference model based approach.

Hence, the method BPTrends Business Process Architecture from Burlton (2015), which applies a reference model based approach, should be regarded as reference for the development of the PSS BPA Development Method.

Requirement 4 – Selecting reference models, BPMLs, and modeling tools

After identifying a strategy for defining the PSS BPA by using a reference model based approach, it is important to understand how to select the appropriate business process reference model for PSS context.

As presented in section 3.2.5.1, there are several business process reference models in academic and professional literature, but only few examples are specific for PSS domain (BECKER; BEVERUNGEN; KNACKSTEDT, 2008; CURIAZZI et al., 2016; GEROSA; TAISCH, 2009). Hence, existing business process reference models from manufacturing and service context should be combined and adapted to envision PSS contexts. Additionally, an updated catalogue of business process reference models to support the application of the PSS BPA Development Method should be created**.** One potential alternative is to complement existing references, such as the *Reference Modeling Catalogue.*

In addition, as presented in sections 3.2.5.2 and 3.2.5.3, one or more business process modeling languages (BPML) and a modeling tool should be selected according to the organizational context to support the generation of the process model. The guidelines for supporting this decision were described in the aforementioned sections.

4 Results and discussion

This chapter presents the results of the third (Prescriptive Study) and fourth (Initial Descriptive Study II) stages of this research, as described in methodology section 2.2.3.

Action research was applied in the Prescriptive Study with two main purposes:

(I) Supporting a manufacturing company in addressing a specific organizational problem during its servitization journey, which was defining the required business process architecture for operating a new PSS business model;

(II) Concomitantly, during the action, a *method* for solving the aforementioned problem called PSS BPA Development Method was developed and improved.

The action research was performed in three cycles that are explained in details in the following sections of this chapter.

This chapter is structured in six sections.

Section 4.1 details the outcomes of the activity “define context and purpose” that is performed only once, before the beginning of the action research cycles.

Sections 4.2, 4.3, and 4.4 describe the process and results of the first, second and third cycles of the action research, respectively.

Section 4.5 presents the final version of the PSS BPA Development Method (satisfying action research’s purpose II) after the improvements of the action research cycles.

Finally, section 4.6 presents the outcomes of the final research stage, Initial Descriptive Study II, summarizing insights about the applicability and usability of the PSS BPA Development Method, and suggesting a complete evaluation plan for future researches.

4.1 Context and purpose

Context

The action research was conducted in a multinational company - here after named ImageCO[37] - that produces equipment for health sector[38]. ImageCO is a large company employing over 1000 workers. The company has strong competences in product development and manufacturing. They have a diverse portfolio, but the family of products selected to become PSS is a diagnostic imaging equipment, which are high cost products manufactured and sold predominantly by means of Business-to-business (B2B) transactions.

The company decided to focus on a PSS strategy after losing successive opportunities to entry new market segments due to customers' economic restrictions on making high investments to buy the equipment. Hence, they want to attract new customers that require specific services related to the product by means of offering PSS.

They required support with methodological knowledge, because they have already unsuccessfully implemented a PSS before based on the same product. According to them, this PSS was configured like a pure rental. It was terminated after one year due to internal operational issues and conflicts with customers (they were expecting to have the maintenance service included in the PSS monthly fee, but they had to pay for it).

ImageCO has a predominant functional organizational structure. However, for conducting the action research, they structured a multifunctional project team constituted of the Market Intelligence and Product Manager, the Engineering Manager, and the Post-Sales Manager. The Marketing Intelligence and Product Manager was selected to coordinate the development of all activities inside the company. Other members of the company were accessed when necessary with the mediation of this facilitator. Furthermore, the Executive Vice-President, the Sales Director, and the New Business Director were involved in specific moments to validate decisions.

As action research approach was adopted, besides guidance and coordination, the researcher also actively participated in the execution of the method's activities. Other ten researchers also participated in some activities as a consequence of the PSS BPA Development Method being developed iteratively and interfacing with other methods of the *PSS Transition Framework*, as explained in section 1.1.

[37] Due to the non-disclosure agreement (n.d.a) signed, a set of information of the company are not allowed to be published and were omitted from this research, including the company's identity.
[38] The company can be classified under the division 28: *Manufacture of machinery and equipment n.e.c.*, of the ISIC Classification Framework.

Purpose

The contributions of this study to the company are: (I) the definition of a business process architecture for operating their PSS, which includes the collection of services processes, required resources (in terms of IT systems), required people, and key performance indicators of the operation; and (II) they also acquire knowledge concerning main implications to implement a PSS, and methods to develop other PSS offers in the future.

The contributions to academia are: (I) the proposal of a method to be applied in servitization processes for defining the Business Process Architecture for operating the MOL and EOL phases of a PSS; and (II) the consolidation of insights and in-depth knowledge from a real experience of a servitization process.

4.2 First action research cycle

The first cycle of the action research had two main goals: developing a first version of the method, which is the *Initial PSS BPA Development Method (D.3.1)* based on theoretical background, and already applying some steps of the method to improve it, proposing a *Transitional PSS BPA Development Method (D.3.2)*. The following sections present the activities performed during the first cycle, as described in section 2.2.3: *diagnose (section 4.2.1), plan action (section 4.2.2), take action (section 4.2.3),* and *evaluate action (section 4.2.4)*.

4.2.1 Diagnose

This activity was performed through verification of documents, informal interviews and observations conducted in parallel with the activities for obtaining the first two deliverables foreseen in the *PSS Transition Framework*: “Business Analysis and Value Proposition” (PIERONI et al., 2016).

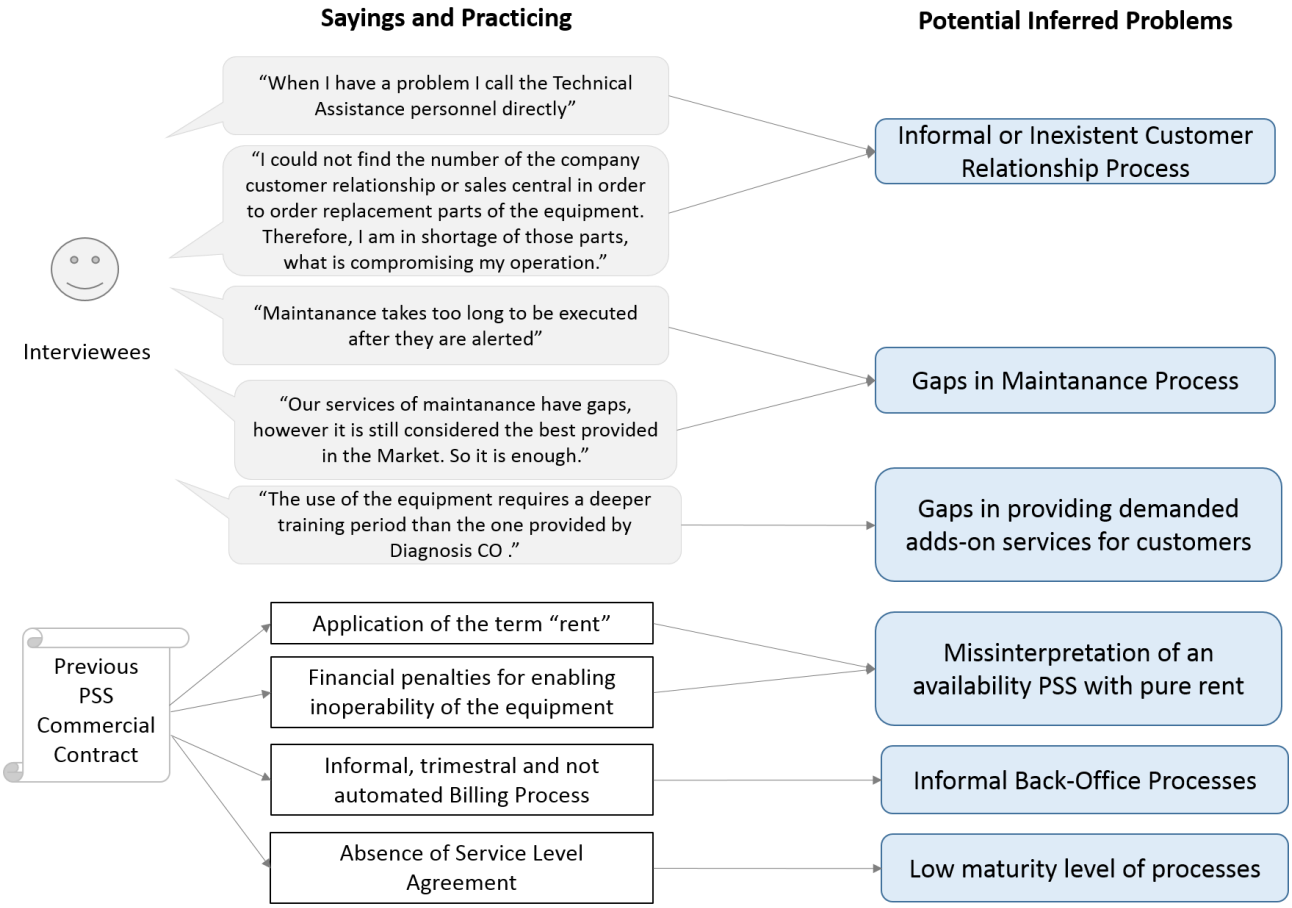
A total of eleven interviews were conducted with internal (Engineering Manager, Marketing Manager, Sales Coordinator, Technical Assistance Manager, and Legal Manager) and external stakeholders (key customers) of the company. The interviews were focused on assessing the generalist context of the company and its previous experience with PSS, which was a step of the *PSS Transition Framework*. Therefore, they did not specifically focused on the business process architecture, and that is why they are classified as informal interviews. Nevertheless, some questions of the semi-structured questionnaires related to process organization and service provision,

enabled the author to collect enough relevant information to infer a diagnosis about the business process architecture in the PSS background.

Besides interviews and observations, one relevant document was selected to be evaluated, which was the PSS commercial contract that the company developed in its previous experience of providing PSS.

As described in section 2.2.3.3.2, collected data (expressions, observations, and text) related to operational processes or quality of service provision were synthetized and organized in problem categories, as depicted in Figure 28.

Figure 28 - Potential problems in the company's BPA



SOURCE: created by the author.

At the end of the *Diagnose* activity, it was confirmed that the company's business process architecture was not prepared to enable the operation of a PSS, once processes related to service provision presented hurdles and low maturity such as informal or inexistent customer relationship process, gaps in maintenance process, and absence of a Service Level Agreement (SLA).

Diagnose activity was conducted only in the first cycle of the action research, because the scenario of the company's business process architecture had not changed by the time the next two cycles were conducted.

4.2.2 Plan action

The purpose of this activity was to structure the steps for the conduction of the action research cycle. The first outcome of this activity was the *Initial PSS BPA Development Method (D.3.1),* which is explained in section 4.2.2.1. Additionally, this activity comprised creating a plan with the activities, dates, and required participants for the execution of the first cycle of the action research (section 4.2.2.2).

4.2.2.1 Initial PSS BPA Development Method

This section describes the *Initial PSS BPA Development Method (D.3.1)*, which is the first deliverable of the Prescriptive Study. It consists of a theoretical framework of potential elements for creating the definitive PSS BPA Development Method. These elements comprise initial deliverables and activities of the method to be fully developed at the end of the action research. These initial deliverables and activities were derived from the *PSS BPA Development Method Requirements (D.2.2)* (section 3.3), as explained in the following topics.

4.2.2.1.1 Requirement 1: Integrating business process architecture development within the definition of the Complete PSS Business Model

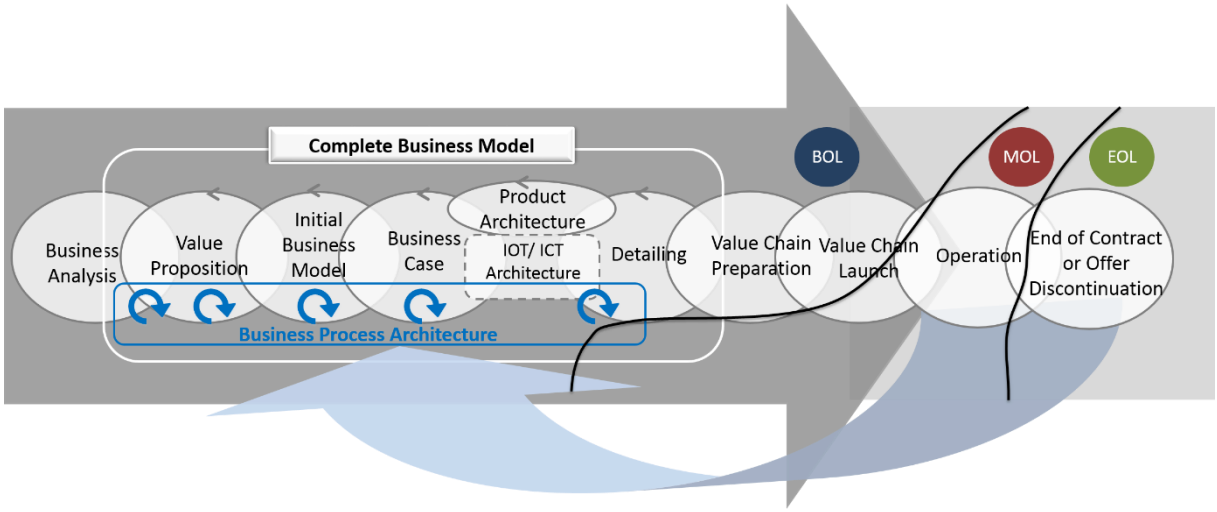
As described in section 3.2.4, establishing alignment between strategy and the organizations' processes is a critical element of a BPA. Hence, for developing the BPA it is necessary to combine different methods in order to connect and translate aspects of strategy and customer's needs into business processes. This reasoning leads to the first requirement for planning the solution (section 3.3): PSS BPA Development Method shall be integrated within the definition of the PSS business model. However, for that, the interpretation of business model adopted in this research must be explained.

<u>The interpretation of business model</u>

As already mentioned in section 1.1, the BPA for operating a PSS is being developed within the scope of a comprehensive approach for servitization process referred to as *PSS Transition Framework* (Figure 29) (PIERONI et al., 2016). The PSS BPA is one deliverable predicted by this framework (blue-bordered box in Figure 29); hence, the

PSS BPA Development Method is one of the methods that support the application of this *PSS Transition Framework.*

Figure 29 – PSS Transition Framework main deliverables



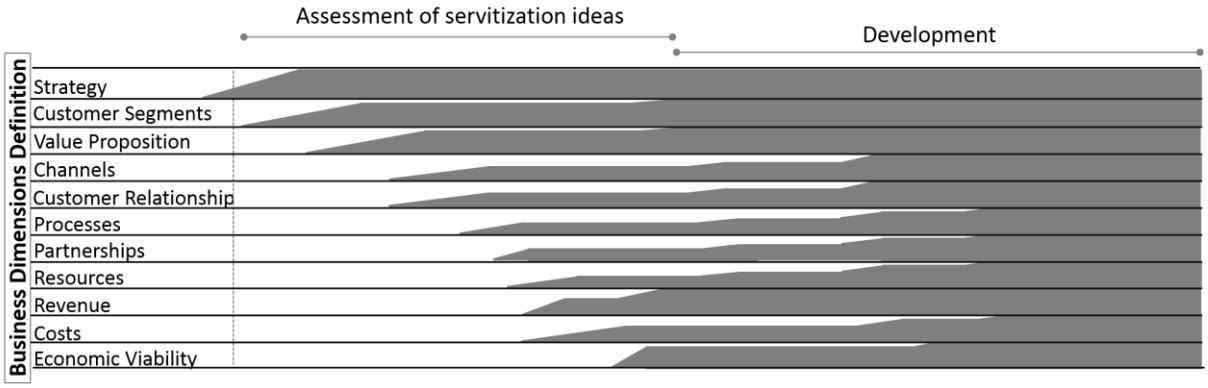
SOURCE: adapted from Pieroni et al. (2016).

The *PSS Transition Framework* involves unfolding the company's strategy step-by-step until it permeates lower organizational levels through processes execution. It considers that there exists a complete PSS Business Model, which encompasses different levels of detailing. In the beginning of the servitization process, when the idea of implementing a PSS is still being assessed, it is possible to obtain only an Initial Business Model with dimensions and its elements being described at a high level of abstraction. Therefore, the complete detailing of all business process dimensions, which delivers the Complete PSS Business Model becomes gradual, occurring parallel with the complete Development phase as illustrated in Figure 30. In some cases, it can occur that some details of the business model, such as adjustments in the value proposition and consequently in the PSS architecture, are only completely determined or refined during the implementation and use phases of the PSS (ABRAMOVICI et al., 2016, p.289). These adjustments may arise because of the customer's ad hoc requirements or better understanding of the day-to-day reality of customers' operations.

For detailing the Complete PSS Business Model, instead of applying one single and generic method, such as the Business Model Canvas (OSTERWALDER; PIGNEUR, 2010), usually presented in literature (ADRODEGARI; SACCANI; KOWALKOWSKI, 2016; XING; NESS, 2016) for defining all dimensions at high level of abstraction, the

PSS Transition Framework requires using interconnected methods to detail each business model dimension involving different areas of knowledge (in accordance with section 3.1.6).

Figure 30 - Gradual definition of the complete PSS business model dimensions



SOURCE: adapted from Pieroni et al. (2016).

An approach based on interconnected methods, such as the *PSS Transition Framework*, enables more detailed and specialized solutions, once expertise from different areas of knowledge is considered to compose the holistic view depicted in the business model. Additionally, it generates more integrated and systemic solutions once the outcomes of the application of a specific method already define variables of subsequent methods as illustrated by the superposition of the deliverables in Figure 29.

The main synergic deliverables of the *PSS Transition Framework* are: "Business Analysis*"* for understanding the company's strategy and objectives towards servitization; "PSS Value Proposition" obtained through the application of "Design Thinking" for identifying customers' needs; "Initial Business Model[39]" obtained by combining aspects of the Business Model Canvas approach (OSTERWALDER; PIGNEUR, 2010), for generating an initial view of all business dimensions, with the PSS-Configurator (BARQUET, 2015), for incorporating PSS aspects and achieving a deeper level of details in the PSS conception; "Business Case" that indicates the PSS economic viability; and "Business Process Architecture" that further details some dimensions from the Initial Business Model, such as processes (including all types of

[39] As explained before in this section, this study differentiates the complete business model, which requires more detailing and is only obtained at the end of the development phase, from the initial business model, which encompasses business dimensions at high level of abstraction and is obtained during the assessment of the servitization ideas.

processes and not just the ones related to service provision), partnerships, and resources.

Since this research is concentrated on developing PSS from existing product, the "Product Architecture" and the "Information and Communication Technology (ICT) Architecture" indicated in Figure 29 already exist. However, they may need updates due to the definition of new processes for service provision or potential modifications in product's or ICT systems' requirements because of PSS particularities. For example, implementing sensors in the product for predictive maintenance (which is inserted in the domain of Internet of Things (IoT)), and adapting the back-office information system for processing the new type of data captured by sensors, as explained in section 3.1.8. Those needs shall be partially identified in terms of products and systems' features during the business process architecture definition. Nevertheless, during the implementation and use phases of the PSS, changes in the BPA may occur (see the blue arrow in the bottom of Figure 29) in order to incorporate new technological opportunities in the PSS solution, such those on the IoT domain (ZANCUL et al., 2016), or new customer requirements.

Although the *PSS Transition Framework* goes further in "Value Chain Preparation", "Value Chain Launching", and "Operation" (Figure 29), this research focuses on the deliverable Business Process Architecture. This deliverable only advances until part of the "Detailing", which comprises defining the process model until the level of *activity*, as explained in the introductory section 1.3.

Role and contributions of the PSS BPA Development Method

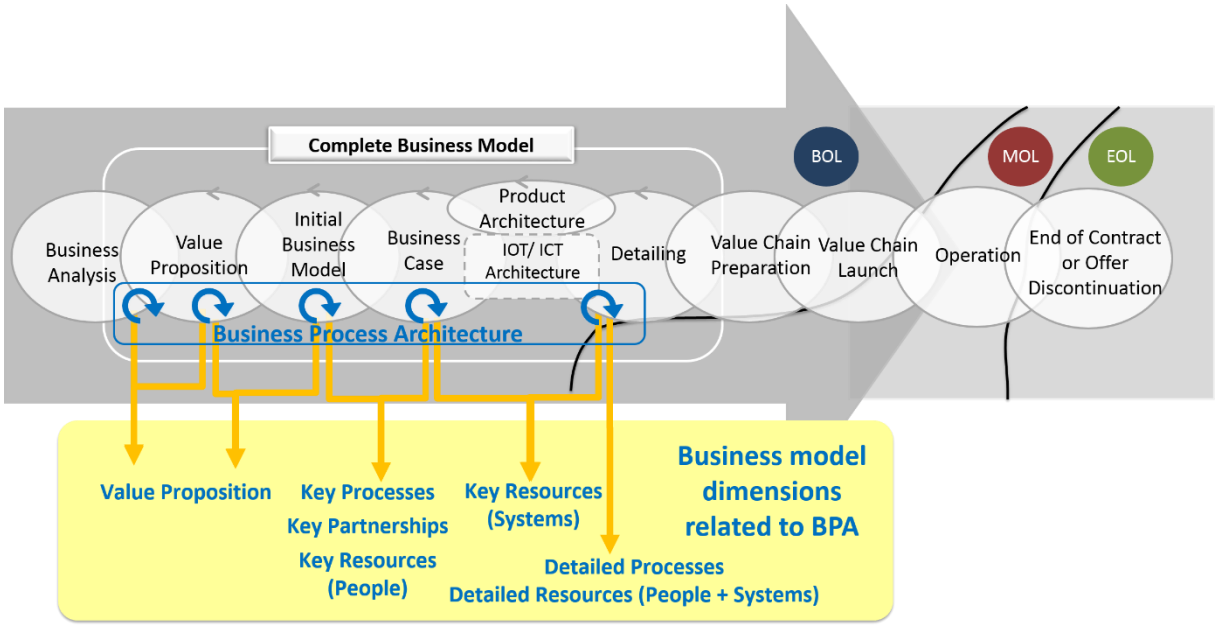
As indicated in literature review section 3.1.9, the future business process architecture for the PSS transition must be clearly defined in light of the current business process architecture to enable the organization to plan the transformation of its capabilities regarding informational systems structure, people, materials, practices and potential partnerships. Accordingly, the BPA is treated in this work as a more detailed level of abstraction of the dimensions "processes, resources, and partnerships" of the complete PSS business model. It includes not only the services' architecture, but also all processes of the business PSS.

Hence, the PSS BPA Development Method is interconnected with different methods from the *PSS Transition Framework*, such as the Business Analysis, the Design

Thinking for proposing the Value Proposition, the Business Model Canvas, the PSS-Configurator, and the Business Case Assessment, in order to support the detailing of the aforementioned business' dimensions. This integration poses the PSS BPA Development Method to be performed gradually along the Development of the servitization process, as illustrated by the blue looping arrows in Figure 29.

Summing up, the synergic application of the PSS BPA Development Method with other methods of the *PSS Transition Framework* is a contribution of this research. It enables the alignment between the company's strategy and its collection of processes described in the BPA. Furthermore, the proposed method shall anticipate the definition of some BPA elements (processes, partnerships, people and resources). Additionally, the application of Business Analysis, and Design Thinking to define the Value Proposition of the Initial Business Model, will ensure that processes' requirements are aligned to customer and end user's needs as illustrated in Figure 31.

Figure 31 - Integrating PSS BPA Development Method with other methods of the PSS Transition Framework



SOURCE: adapted from Pieroni et al. (2016).

4.2.2.1.2 Requirements 2 and 3: deliverables and activities of the initial version of the PSS BPA Development Method

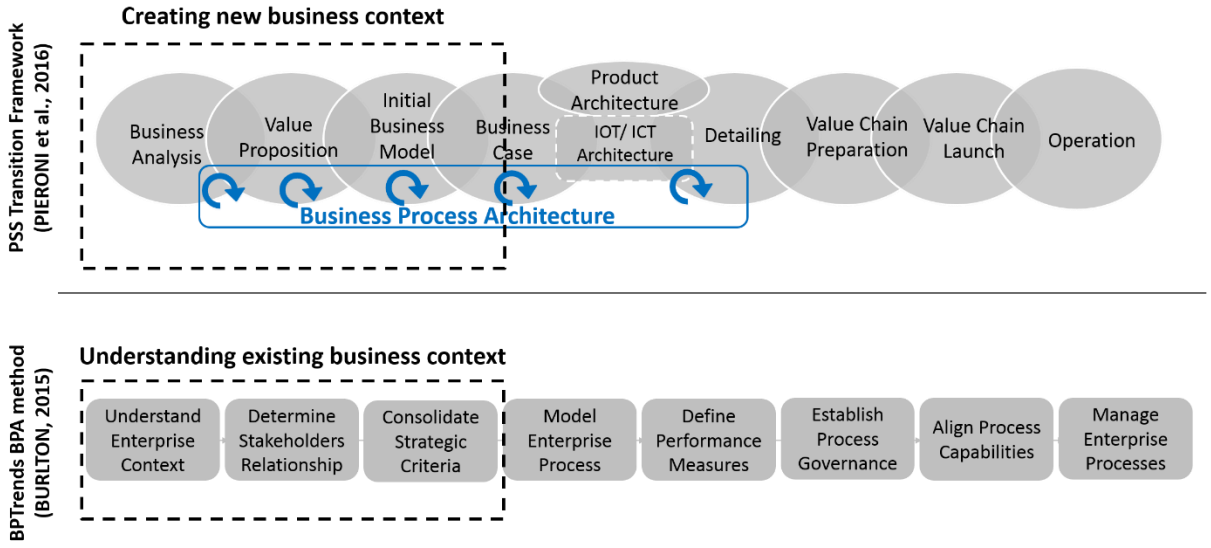
<u>The logic behind the Initial PSS BPA Development Method</u>

The second requirement states that a business process architecture encompasses five fundamental elements as described in section 3.2.5.2: "processes hierarchical view

(E1)", "processes end-to-end view (E2)", "alignment between processes and organizational strategy (E3)", "alignment between processes and resources (E4)", and "measurement and change mechanisms (E5)". The third requirement (section 3.2.5.2) identifies that the *BPTrends Business Process Architecture* method from Burlton (2015), should be considered as reference for the development of the PSS BPA Development Method, because it encompasses all five aforementioned critical elements and uses a reference model based approach.

Therefore, an initial version of the activities and deliverables of the PSS BPA Development Method is derived from the BPTrends Business Process Architecture method (BURLTON, 2015) and the five critical elements of BPA (AREDES; PÁDUA, 2014). The logic behind this derivation is depicted in Figure 32 and Figure 33.

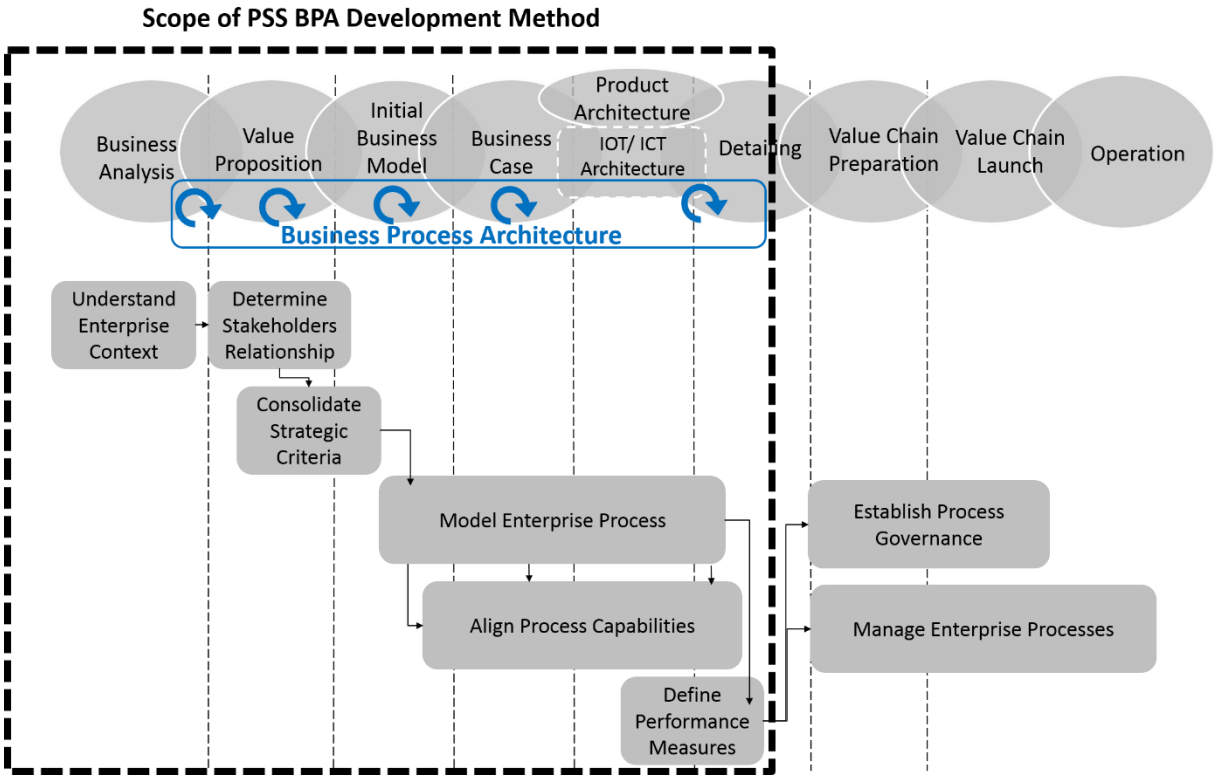
Figure 32 - Differences in focus of PSS Transition Framework (top) and the BPTrends BPA method (bottom)



SOURCE: created by the author.

As already explained in Requirement 1, the PSS BPA Development Method occurs in the context of the servitization process and interconnected with other methods from the *PSS Transition Framework*. The servitization process focus in the development of a process architecture for operating a new type of business while its logic (business model) is being proposed. This requires an in depth analysis of aspects that are changing or being created as a consequence of the servitization, such as the definition of the value proposition and the concept of the new product-service bundle being offered, before focusing on the aspect of processes structure.

Figure 33 – Initial view of the occurrence of BPTrends BPA method's activities (bottom) in the PSS Transition Framework (top)



SOURCE: created by the author.

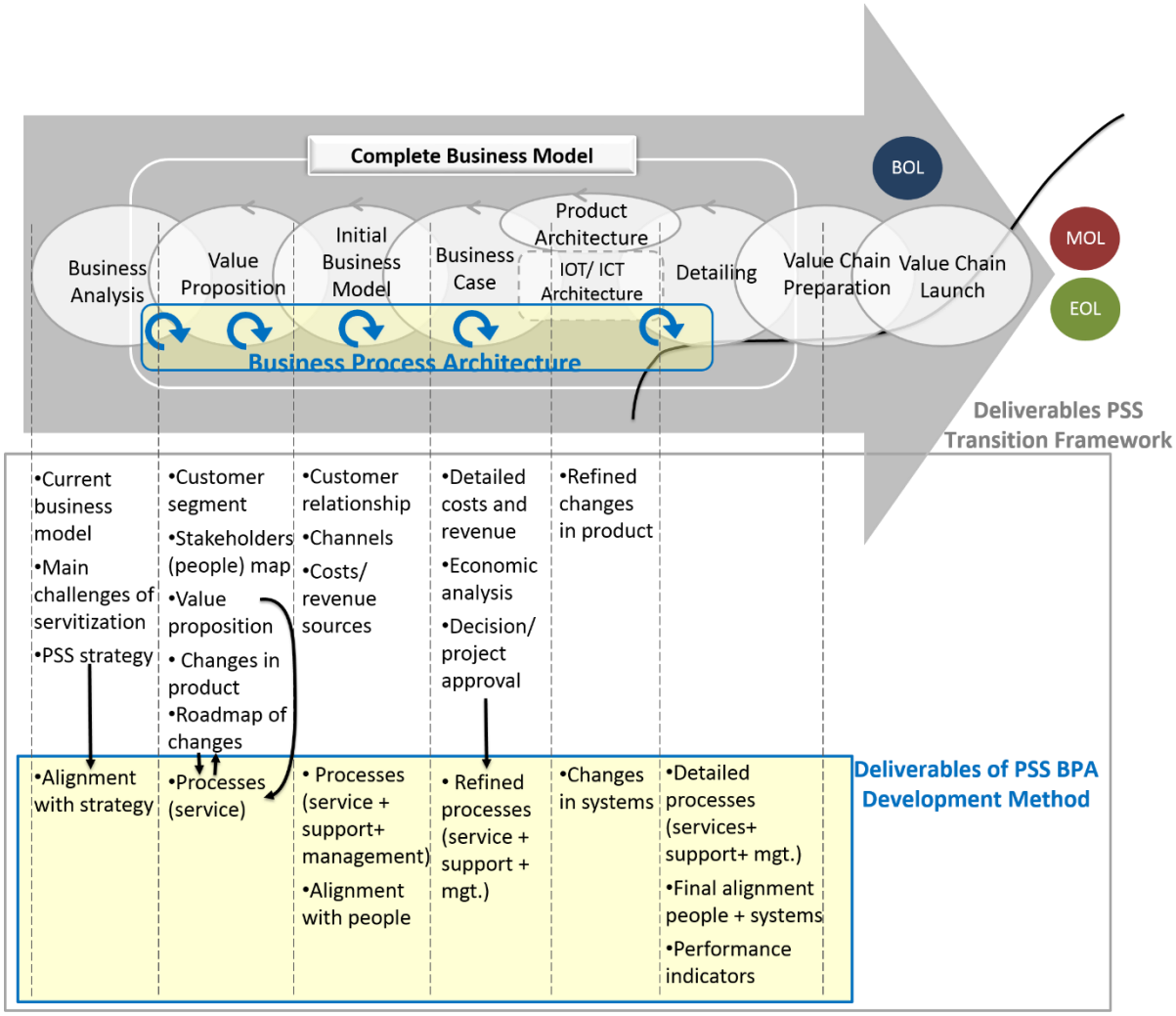
On the other hand, the BPTrends Business Process Architecture method proposed by Burlton (2015) focus on the development of a process architecture in an existing business. Therefore, it does not involve proposing a concept for the new value proposition. Instead, it involves understanding the existing business context. Hence, while in the servitization process the first activities for defining a BPA aim at configuring or creating the business context (value proposition + business model), in the BPTrends BPA method, the first activities aim at understanding an existing business context, as depicted in Figure 32.

Therefore, the activities proposed by the BPTrends Business Process Architecture method had to be adapted for the servitization context. Some of the activities predicted in the BPTrends BPA method are determined through the application of methods proposed by the PSS Transition Framework, which are specific for the context of creating new business and new value propositions. Before showing the result of this adaptation, which generated the PSS BPA Development Method, Figure 33 shows where in the PSS Transition Framework each activity of the BPTrends BPA method is obtained.

Initial PSS BPA Development Method

Inspired by the logic depicted in Figure 33, an initial version of the PSS BPA Development Method was proposed, representing the first deliverable of the third stage of this research, the *Initial PSS BPA Development Method (D.3.1)*, which shall be refined during the action research. Two views of the PSS BPA Development Method were generated: the "deliverables view" illustrated by Figure 34, and the "activities view" depicted in Figure 35.

Figure 34 - Initial PSS BPA Development Method: deliverables view



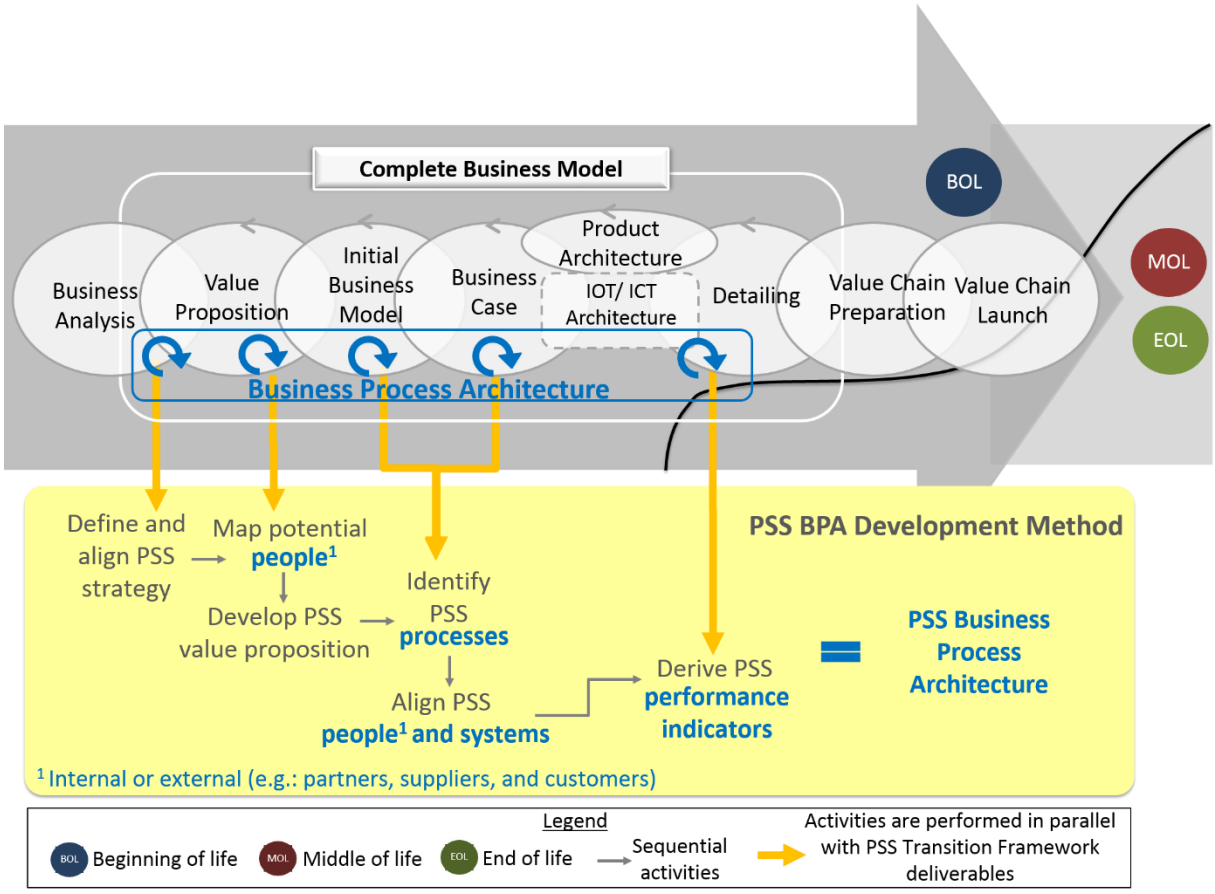
SOURCE: created by the author.

As previously explained in introduction section 1.1, the PSS BPA Development Method is comprised within the *PSS Transition Framework*. Therefore, the deliverables of the PSS BPA Development Method (indicated inside the rectangle with blue borders in

Figure 34) are also deliverables of the *PSS Transition Framework* (described inside the gray-bordered rectangle in Figure 34).

Figure 34 illustrates that some of the deliverables of the *PSS Transition Framework* are fundamental for the definition of the deliverables of the PSS BPA Development Method. For example, the Value Proposition defined by other method of the PSS Transition Framework is crucial for determining the processes related to services in the PSS BPA Development Method.

Figure 35 - Initial PSS BPA Development Method: activities view



SOURCE: created by the author.

The initial version of the PSS BPA Development Method comprises six activities, as depicted in Figure 35:

1) Define and align PSS strategy
2) Map potential people[40]

[40] As explained in literature review section 3.2.5.2, the aspect “people” may comprise an *organizational unit*, which can be internal or external (such as customers and partners), or a *role*.

3) Develop PSS value proposition
4) Identify PSS processes
5) Align PSS people and systems
6) Derive PSS performance indicators

These activities are performed within other methods being applied in the PSS Transition Framework for obtaining other deliverables, as illustrated by the blue rounded corner rectangle in Figure 33. The yellow arrows indicate when these activities are being performed in respect to the other deliverables occurring in the servitization process. Note that, the main elements of the BPA (highlighted in blue) based on Aredes and Padua (2014) are part of the name of some activities.

Steps, tools, and deliverables of the PSS BPA Development Method are developed and improved during the action research cycles, as explained in sections 4.2.3, 4.3.2, and 4.4.2.

4.2.2.1.3 Requirement 4: Selecting and adapting the business process reference model

The Business Process Reference Models Catalogue

The fourth requirement (section 3.3) states that existing reference models from manufacturing and services field should be combined or adapted to obtain new models for PSS scope. Hence, the activity “Identify PSS processes” (Figure 35) is obtained with the support of business process reference models.

An updated catalogue called Business Process Reference Models Catalogue[41] was created to support the execution of the activity “Identify PSS processes” of the PSS BPA Development Method. This catalogue was created by means of literature review. Since the idea was generating an initial and updated version of the most relevant reference models to support the selection in the action research, the search was not systematic. Therefore, there may exist other business process reference models that were not included in the catalogue. The full catalogue is presented in Appendix C. It contains 31 business process reference models. The following information is shown for each model:

[41] This catalogue was developed with the support of the undergraduate student Paulo Vinicius Castagnari as part of his final course project and under the supervision of the author of this work.

- Name of the business process reference model
- Type (Business Process Blueprints/Reference Process Models or Standards)
- Abstraction level (Detailed or Conceptual),
- Domain (Manufacturing, Services or Generic)
- Sector
- Origin (Academy, Consultancy, Research Organization, Government, Industry, Industry Consortium, Standards Organization)
- Author
- Purpose
- Description
- Number of citations
- Access (public or restricted)

Comparing and selecting a business process reference model for the action research

In order to select a business process reference model for the action research, 14 from the 31 reference models comprised in the Business Process Reference Models Catalogue were selected for the conduction of a comparative analysis[42], as presented in Table 12. Only 14 reference models were selected for the analysis because they were the ones with greatest relevance either in occurrences of citation or because they were oriented to PSS domain. The analysis consisted of evaluating each business process reference model in two categories of criteria:

(I) **Ability of offering support to the definition of a Business Process Architecture:** encompasses four criteria – Hierarchical view, End-to-end view, Alignment with Strategy, and KPI - that are based on the critical elements of a BPA, as described in section 3.2.4. The element “Alignment between processes and resources (IT and people) (E4)” (see section 3.2.4) was not included as a criterion, because generally they are defined according to each organizational context and can be represented only in the specific process models already instantiated, which is not the case of the generic reference models being assessed.

Table 7 also indicates, bellow the criterion “Hierarchical View”, the level of hierarchical subdivision of each model. It is necessary that a model details

[42] The analysis was also developed with the support of the undergraduate student Paulo Vinicius Castagnari as part of his final course project and under the supervision of the author of this work.

processes until the level of activities[43] for it to be considered suitable for the definition of a PSS BPA. Nevertheless, some models may go further in this detailing, reaching the level of tasks.

(II) **Ability of offering support to the operation of a PSS:** encompasses seven criteria based on necessary capabilities of a PSS Value Chain proposed by Bagheri, Kusters, and Trienekens (2014) (section 3.1.8), and PSS strategic characteristics proposed by Tan (2010) (section 3.1.2).

The capabilities “Trust-based interaction” and “Engagement” proposed by Bagheri, Kusters, and Trienekens (2014) were merged in the criterion “Partnership”, because they are similar and can be interpreted as immediate consequences or extensions of each other. Two additional capabilities based on the characteristics proposed by Tan (2010) were proposed: “PSS Life-cycle and End-of-Contract management”, and “Revenue enabling”.

The business process reference models’ are then evaluated in each criterion according to three level of adherence: 0 – The model does not comprehend the criterion; 1 – The model partially comprehend the criterion; 2 – The model comprehend the criterion. The complete list of criteria and the qualitative parameters explaining the aforementioned levels of adherence for each criterion are available in Appendix D.

According to Table 12, the Process Classification Framework (PCF) is the most appropriate reference model for supporting the definition of a BPA and the operation of a PSS, because it encompasses at least partially all required criteria. This suggests that applying the PCF for proposing a business process architecture for the operation of a PSS may take less time and effort in the adaptation and configuration of the processes’ structure. Nevertheless, it presents gaps related to the definition of KPIs and the provision of some fundamental operational processes for the MOL and EOL phases of the PSS value chain, such as PSS design and delivery, partnership development and management, end of life and end of contract management, and revenue enabling. Hence, this confirms the necessity of combining and adapting already existing business process reference models from manufacturing, services or generic fields to the PSS context.

[43] The meaning of each process level is explained in literature review section 3.2.1.

Table 12 – Comparative analysis of business process reference models[44] (created by the author)

	Business Process Reference Models[1]													
Criteria of Assessment	**Most referenced in literature**											**Oriented to PSS**		
BPA Elements	SCOR	ITIL	CMMI AQC	CMMI DEV	CMMI SVC	PCF	eTOM	Y-CIM	VRM	COBIT	CCOR	IRM	Becker et al. (2010)	Curiazzi et al. (2016)[2]
Hierarchical view	2	2	2	2	2	2	2	2	2	1	2	2	2	2
Process														
Subprocess														
Activities														
Tasks														
End-to-end view	1	1	1	1	1	2	2	0	1	1	1	1	0	N/A
Alignment with strategy	0	1	1	1	1	2	2	0	2	2	0	0	0	N/A
KPIs	2	0	0	0	0	1	0	0	0	2	2	2	0	N/A
Partial Result BPA	**5**	**4**	**4**	**4**	**4**	**7**	**6**	**2**	**5**	**6**	**5**	**5**	**2**	**2**
PSS Capabilities														
Customer understanding	0	0	1	2	2	2	0	0	1	0	2	2	2	N/A
Partnership	0	2	2	2	2	1	2	0	1	2	0	0	1	N/A
PSS design & delivery	0	0	0	1	2	1	0	0	0	0	0	0	1	N/A
Process management	0	0	0	1	2	1	0	0	0	0	0	0	0	N/A
Knowledge management	0	1	0	0	0	2	1	0	0	1	2	1	0	N/A
PSS Life-cycle and End-of-Contract management	0	0	0	0	0	1	1	0	1	0	0	1	0	N/A
Revenue enabling	0	0	0	0	0	1	0	0	0	0	1	0	0	N/A
Partial Result PSS	**0**	**3**	**3**	**6**	**8**	**9**	**4**	**0**	**3**	**3**	**5**	**4**	**4**	**2**
Result	**5**	**7**	**7**	**10**	**12**	**16**	**10**	**2**	**8**	**9**	**10**	**9**	**6**	**4**

SCOR: Supply Chain Operations Reference Model (SUPPLY CHAIN COUNCIL, 2010a); **ITIL**: IT Infrastructure Library (IT PROCESS MAPS GBR, 2009); **CMMI AQC**: Capability Maturity Model Integration for Acquisition (TEAM, 2010a); **CMMI-DEV**: Capability Maturity Model Integration for Development (TEAM, 2010b); **CMMI-SVC**: Capability Maturity Model Integration for Services (TEAM, 2010c); **PCF**: Process Classification Framework (APQC, 2015); **eTOM**: Enhanced Telecom Operations Map (TM FORUM, 2011); **Y-CIM**: Y(-shaped)-Computer Integrated Manufacturing Reference Model (SCHEER; JOST; GUNGOZ, 2007); **VRM**: Value Reference Model (VALUE CHAIN GROUP, 2015); **COBIT**: Control Objectives for Information and Related Technology (ISACA, 2012); **CCOR**: Customer-Chain Operations Reference-Model (SUPPLY CHAIN COUNCIL, 2010b); **IRM**: Industrial Services Reference Model (GEROSA; TAISCH, 2009). For more information, see Appendixes C and D.

[2] This reference model is still being developed; therefore, some criteria could not be assessed due to absence of information.

[44] This table was adapted from the final course project developed by the undergraduate student Paulo Vinicius Castagnari.

Process Classification Framework (PCF)

The PCF was created by the American and Productivity Quality Center (APQC) to facilitate process management and improvement. It provides a general architecture (including business processes, performance metrics and best practices) for all business processes of an enterprise, such as operating (core or primary), management and supporting services processes.

The processes are described with 5-level hierarchy: Category, Process Group, Process, Activity, and Task. The PCF contains 13 process categories as described in Figure 36. To assure a pattern, the levels of the PCF are renamed according to the terminology adopted in this study, as described in section 3.2.1. The equivalences are explained in Table 13.

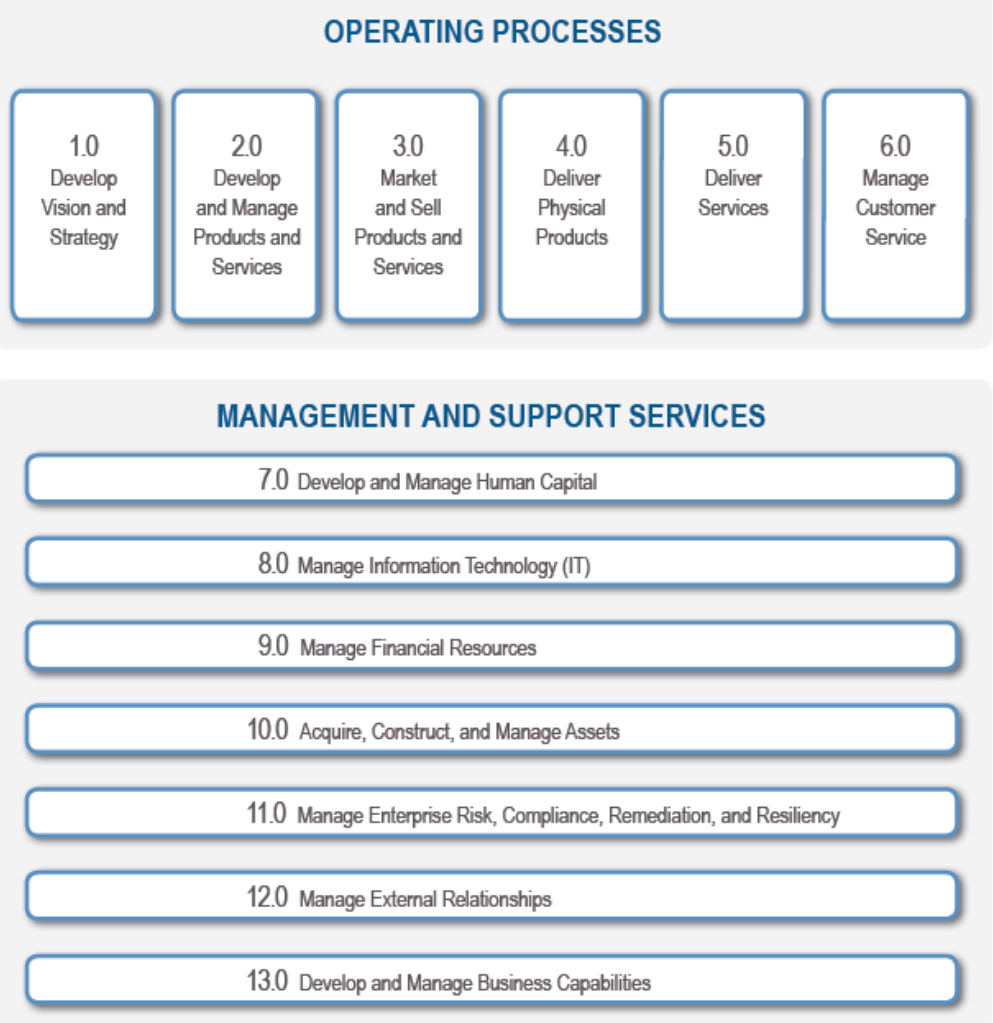
Table 13 - Equivalence of PCF levels in this research's terminology

Level	PCF levels	Equivalence in this research
1	Category	Business process/ Macroprocess
2	Process Group	Process
3	Process	Subprocess
4	Activity	Activity
5	Task	Not applicable

SOURCE: created by the author.

One advantage of PCF is its flexibility that enables support for modeling either manufacturing or services delivery processes. Furthermore, its original version has a cross industry approach, which contributes to its adaptability to any context. Nevertheless, this hinders its applicability to certain specific industries. To treat that issue, from the generic cross-industry view, APQC developed specific frameworks for some sectors such as: Aerospace and Defense, Airline, Automotive, Banking, Broadcasting, City Government, Consumer Electronics, Consumer Products, Downstream Petroleum, Petroleum, Education, Healthcare Provider, Health Insurance Payor, Pharmaceutical, Insurance, Retail, Telecommunications, Upstream Petroleum, and Utilities.

Figure 36 - Process Classification Framework



SOURCE: APQC (2015).

Adaptation of PCF for PSS operation

The PCF was selected to support the definition of the “key processes” and consequently the Business Process Architecture for company ImageCO. Besides having a generic nature, which enables the adaptation to different company contexts, PCF demands less effort in being adapted to support the definition of business processes for the operation of a PSS, as explained above. However, it required some adaptations related to the provision of services to be applied in the PSS context of this action research.

The first adaptation applied in the original PCF consisted of configuring processes directly related to each PSS service type (as illustrated in Figure 11) into the PCF structure.

Inspired by the model of Gerosa and Taisch (2009) - described in section 3.2.5.1 - two hierarchical levels related to PSS services' specifications were incorporated in the PCF structure, under the macroprocess "Deliver services" (level 1), which was substituted by the name "Provide services" in this cycle. These two levels are explained in the following topics:

Level 2 (Processes)

It relates the types of services delivered in the PSS offer. The collection of processes at this level should match the company's service "portfolio". Hence, a specific process is determined for each service offer. As already pointed in section 3.2.5.1, the services proposed by Gerosa and Taisch (2009) do not exhaust the possibilities of services during a PSS life cycle. Therefore, an improvement was proposed, and the service processes' options were obtained from the PSS typology from Becker, Beverungen, and Knackstedt (2010; 2008), as described in section 3.1.3. Figure 37 highlights in the blue box the first level of the generic reference model for services incorporated under the first level of PCF model. Therefore, this level of the generic reference model becomes the second level of the adapted PCF. Each process at this level 2 is entitled "Provide x service", in which "x" may be substituted by any service type depicted in white rectangles, as illustrated in Figure 37.

Also at this first level, there are other three processes (indicated with blue letters) that are not related directly to providing services, however they support and are fundamental for guaranteeing the availability and deliver of the aforementioned services. Those are "Manage Customer Service", "Manage Partnerships", and "Provide Technical Assistance". These processes were introduced after the suggestion of Gerosa and Taisch (2009).

For the specific case of ImageCO, the following services were selected from the reference model to compose the company's specific BPA: Logistics services (equipment transportation and installation); Use training services (related to the equipment's ramp-up, operation, and calibration); Qualification training services (related to patients' positioning and software parametrization in order to improve the quality of the produced image); Predictive and Corrective maintenance services; Consulting services (diagnosis endorsement); Up-grade services (related to the upgrading of software or equipment); Disassembly services; and Product's

end of life management services. These processes are presented in the next section 1324.2.3 (illustrated in blue lines in Table 14).

Level 3 (Subprocesses)

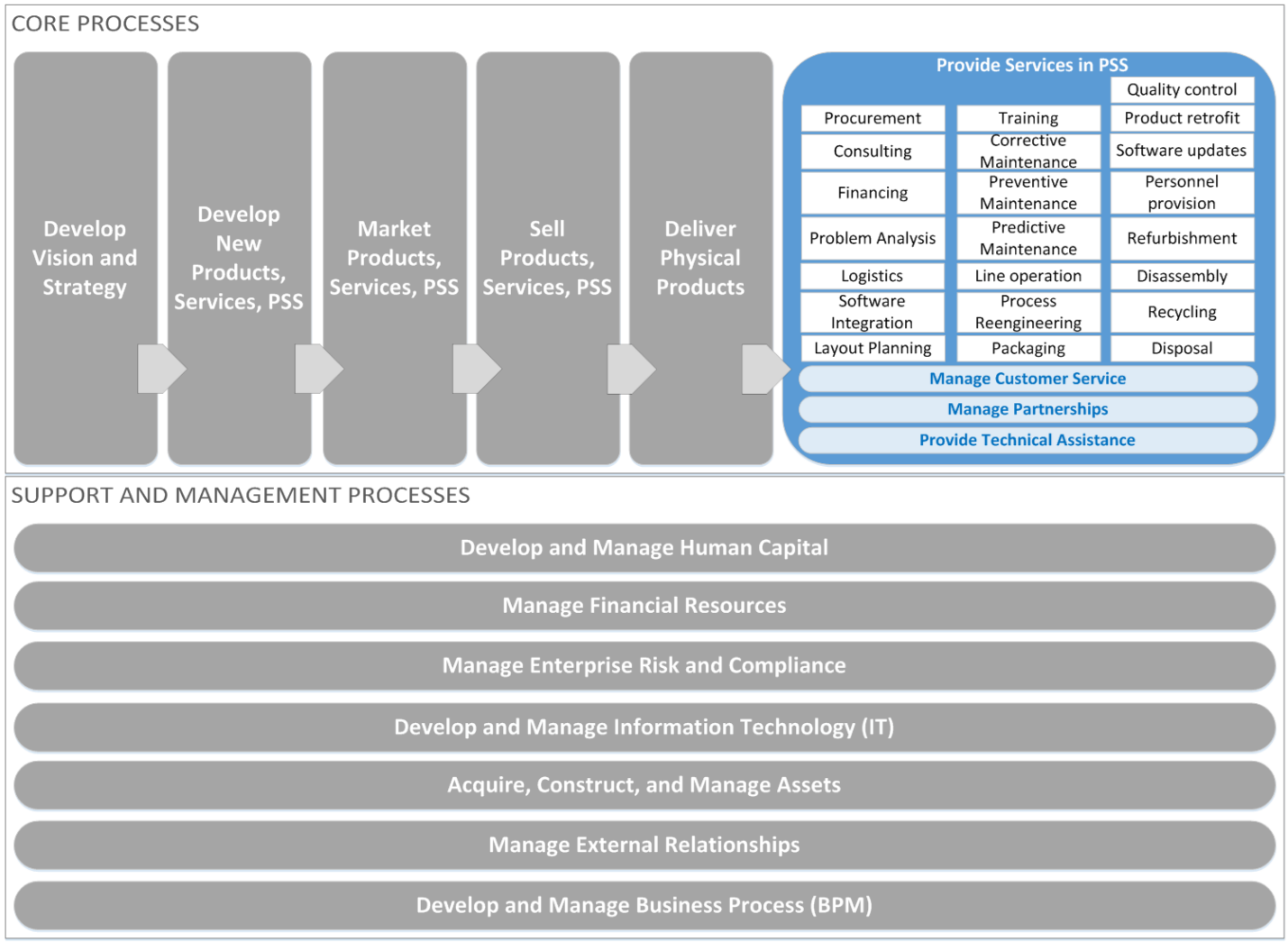
Level 3 details each process identified from level 2 in subprocesses according to the scope of each service offering. It considers a service life cycle perspective, going from the first contact (MOL phase) to the discontinuation of a specific service (EOL phase) (GEROSA; TAISCH, 2009) and are generic, as they apply to any organization independent of context. Three generic subprocesses were considered: “Develop *x* service”, “Manage *x* service”, and “Deliver *x* service”, where “*x”* represents one service option (see white boxes in Figure 37) from the level 2 of the macroprocess “Provide services”. These subprocesses were adopted from the PCF structure for generic services.

“Develop *x* service” comprises activities related to the development or adaptations of the services’ components in existing PSS offers or contracts. This differs from the process “Develop New Product, Service, PSS”, which focus on developing new PSS offers. “Develop *x* service” involves designing the changes to improve the services and adapt their governance if necessary.

“Manage *x* service”, constantly verifies the existing capability associated to each service offer against the market potentials in order to support adequate services’ delivery. It involves activities that are essential for a management cycle such as: planning the actions, doing what was planned, controlling the results, and acting to correct and improve actions. The implementation of this subprocess may be easier or more complex depending on the maturity level of each organization in process management. This discussion concerning the evaluation of organizations’ maturity levels is out of the scope of this study, and remains as a topic for future researches.

“Deliver *x* service” encompasses activities directly related to the customers, which comprises contracts’ elaboration, services customizations, and solution provision until services’ termination. These decompositions are presented in the next section 4.2.3 (illustrated in blue lines in Table 14 on page 140).

Figure 37 – Generic PSS Business Process Reference Model based on the Process Classification Framework



SOURCE: adapted from APQC (2009).

Adaptation of the Initial Business Model tool

In order to enable the integration between PSS Initial Business Model and PSS BPA, which is one important contribution of this work, the aforementioned adapted PCF structure was incorporated in the technical procedure as a checklist for defining the PSS initial business model elements “key processes”, “key resources” (which are represented by “functional areas”, or other types of “resources” such as materials or systems in Figure 38), and “key partnerships” (which are represented by “supplier” in Figure 38). Figure 38 provides an excerpt of the generic tool that was used to support ImageCO’s Initial Business Model detailing. The left column shows the initial structure of the new PSS business process reference model based on the PCF. This tool enables including new processes or adapting existing ones if necessary during the action research.

Figure 38 – Tool applied during the initial PSS business model definition

		Key Resources and Partnerships													
Level	Process/Sub-Process	Functional Area A	Functional Area B	Functional Area C	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Resource A	Resource B	Resource C			
	CORE PROCESSES														
1	**Develop Vision and Strategy**														
1	**Develop Product, Services or PSS**														
1	**Maket Product, Services or PSS**														
1	**Sell Product, Services or PSS**														
1	**Deliver Physical Products**														
	Provide Services														
1	Procurement														
1	Consulting														
1	Financing														
1	Problem Analysis														
1	Process Reengineering														
1	Software Integration														
1	Layout Planning														
1	Training														
1	Documentation														
1	Corrective Maintenance and repair														

SOURCE: created by the author.

4.2.2.2 Project plan

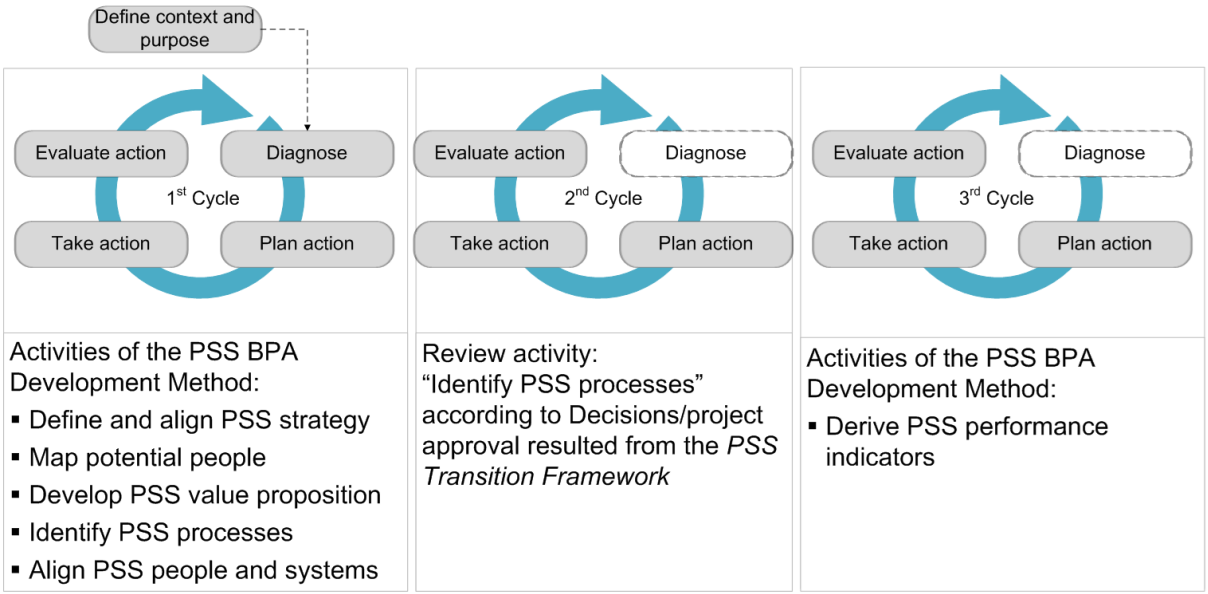
The Marketing and Sales Manager acted as a facilitator and supported the author in developing an initial project plan comprising the activities, dates, and required participants for the execution of the first cycle of the action research.

The action was planned to be performed in three cycles, as presented in Figure 39:

- [1st Cycle] execution of the activities “Define and align PSS strategy”, “Map potential people”, “Develop PSS value proposition”, “Identify PSS processes” and “Align PSS people and systems” of the PSS BPA Development Method;
- [2nd Cycle] review of the activity “Identify PSS processes” according to the “Decisions/project approval” (see Figure 34 on page 118);
- [3rd Cycle] execution of the activity “Derive PSS performance indicators” of the PSS BPA Development Method.

Each action research cycle is normally composed by the main activities: *Diagnose, Plan action, Evaluate action* and *Take action*. Note that the activity *Define context and purpose* is performed only once before the beginning of the action research, as explained in section 4.1. However, in the case of this research, the activity *Diagnose* is performed only in the first action research cycle (they are not filled in gray in the other cycles), as already explained in section 4.2.1.

Figure 39 – Initial action research cycles



SOURCE: created by the author.

The activities of the PSS BPA Development Method comprised in the first action research cycle “Define and align PSS strategy”, “Map potential people”, “Develop PSS value proposition”, “Identify PSS processes” and “Align PSS people and systems”) were conducted in parallel with the execution of other activities of the PSS Transition

Framework for obtaining the servitization deliverables “Business Analysis”, “Value Proposition”, and “Initial Business Model”, as explained in sections 4.2.2.1.1 and 4.2.2.1.2. They involved the following arrangements and participants:

Business Analysis

- 11 interviews with internal (Engineering Manager, Marketing Manager, Sales Coordinator, Technical Assistance Manager, and Legal Manager) and external stakeholders (key customers);
- Participation of: 3 MSc researchers (including the author of this study), and ImageCO Project Leader.

Value Proposition

- 10 workshops;
- 16 interviews with different stakeholders related to the existing diagnostic imaging equipment (current clients, possible future clients, competitors’ clients, bank institutions, 3 internal employees);
- 6 interviews with key customers for testing the prototypes;
- Participation of: 1 Professor, 1 PhD researcher, 3 MSc researchers (including the author of this study), and ImageCO multidisciplinary project team.

Initial Business Model

- 2 workshops;
- Participation of: 4 Professors, 1 PhD researcher, 2 MSc researchers (including the author of this study), and ImageCO multidisciplinary project team. Furthermore, the Legal Manager contributed in specific moments in order to solve legal questionings.

The arrangements and participants involved in the other two action research cycles are explained in the “plan action” sections of cycles 2 and 3 (sections 4.4.1 and 4.3.1, respectively). The subsequent section describes the results of the action taken during the first cycle of the action research.

4.2.3 Take action

As already presented in section 4.2.2.2, during the *Take Action* of the first cycle, the first five activities of the PSS BPA Development Method were performed. The steps and tools applied in their execution as well as their outcomes are explained in the subsequent topics.

1) "Define and align PSS strategy"

This activity consisted of understanding the current organizational context (which occurred along with the delivery of the Business Analysis in the *PSS Transition Framework*) in order to determine the PSS strategy that will guide the definition of the company's processes, as described in section 4.2.2.2.

For understanding the current organizational context (Business Analysis), an assessment of the current business model of ImageCO based on internal aspects (SWOT analysis) and external aspects (as indicated by the Business Model Generation Methodology, these aspects comprise: key regulatory, technological and cultural trends; macro-economic forces; industry forces; and market forces) was performed (OSTERWALDER; PIGNEUR, 2010). This assessment comprised 11 non-directive interviews with different publics, as already explained in sections 2.2.3.3.2 and 4.2.1.

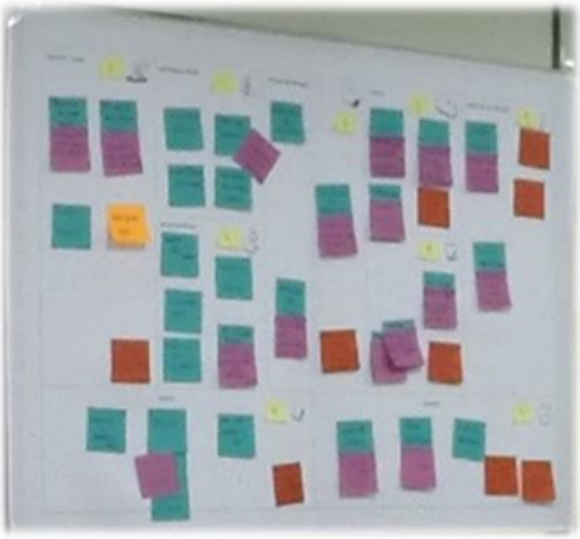
The following deliverables were generated as outcomes of the first activity, "Define and align PSS strategy":

- ImageCO's current business model[45], as depicted in Figure 40.
- Declaration of strategic motivations for offering the PSS:
    - ImageCO was losing several opportunities to entry new market segments (Business-to-consumer (B2C)) due to customers' economic restrictions on making high investments to buy the equipment;
    - ImageCO aims to increase its market share by penetrating in a new market segment (B2C) that is 10 times bigger than the current market (B2B) and in which customers require specific services;

[45] As already mentioned, due to confidentiality reason, the information of ImageCO's current business model cannot be disclosed in this work. Therefore, only the illustrative picture of the real generated business model - based on the framework of the Business Model Canvas presented in section 3.1.4 - is presented here.

- ImageCO wants to increase profit margin when compared to the product category, besides obtaining a continuous monthly revenue.

Figure 40 – ImageCO's current business model[46]



SOURCE: author's archive of pictures.

- List of the main challenges for providing the PSS:
  - This industry's sector presented a gap in offering corrective maintenance services;
  - The sector is still informal, missing important concepts such as service level agreements (SLA);
  - There was demand for training services and preventive maintenance;
  - The provision of PSS to B2C could incur in some conflicts of interests with current clients (B2B);
  - ImageCO had already tried and failed in a previous experience with providing PSS with the same product, as indicated in the "context and purpose" section 4.1.

2) "Map potential people"

[46] As already mentioned, due to the signed n.d.a, the original image was intentionally blurred in order to omit the confidential information concerning the company's business model.

This activity consists of identifying the potential stakeholders[47] of the future PSS offer, which may become the "people[48]" related to the PSS operational processes in the BPA, as well as their relationship and interfaces with the PSS.

It was performed with the support of some methods adapted from the Bootcamp Bootleg Design Thinking approach (PIERONI et al., 2016; ROSA et al., 2016), which was applied for developing the Value Proposition (which is the next topic of this section).

The first method applied consisted of a brainstorming session with ImageCO's project team for identifying all the stakeholders that were currently directly or indirectly involved with the diagnostic imaging product and could be potential stakeholders of the PSS. The identified stakeholders were inserted in a map (see Figure 41) according to their level of interface with the diagnostic imaging product.

The second method consisted of selecting the key stakeholders, which were those that would be more involved with a PSS offer, and representing their relationships and interfaces with the PSS offer by means of using storyboards (see Figure 42). The representation of such relationships may be interpreted as the service experience, or services processes of the PSS offer.

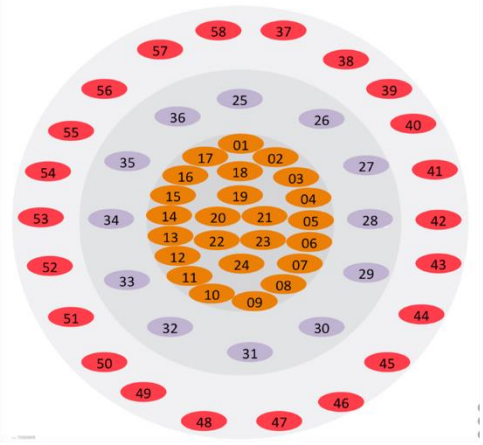
The following deliverables were generated as outcomes of the activity "Map potential people":

- Stakeholders map: list of direct and indirect stakeholders with the indication of the proximity of their relationship with the current diagnosis imagining product (omitted with a white circle in the middle of the left picture due to the n.d.a. restrictions) – internal (orange ellipses), intermediary (purple ellipses), and external (pink ellipses), as depicted in Figure 41.

[47] Stakeholder is a term commonly used in project management field with the meaning of "an individual, group, or organization who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" (PMI, 2013, p. 562). The development and launching of a PSS offer is considered a project for the organization. Therefore, the term stakeholders applies in this context.

[48] The term "People" is usually applied in business process management (BPM) field, specifically in modeling. In this study, "People" is considered as an *organizational unit*, which can be internal or external (such as customers, partners), or a *role* that performs or is involved in the execution of a specific process, subprocess, or activity. Therefore, some stakeholders of the PSS offer development project become "People" involved in the PSS operational processes. Although the activity 2 could be called "Map potential stakeholders", since the PSS BPA Development Method is inserted in the modeling context, the term "People" is adopted.

Figure 41 - Stakeholders' map

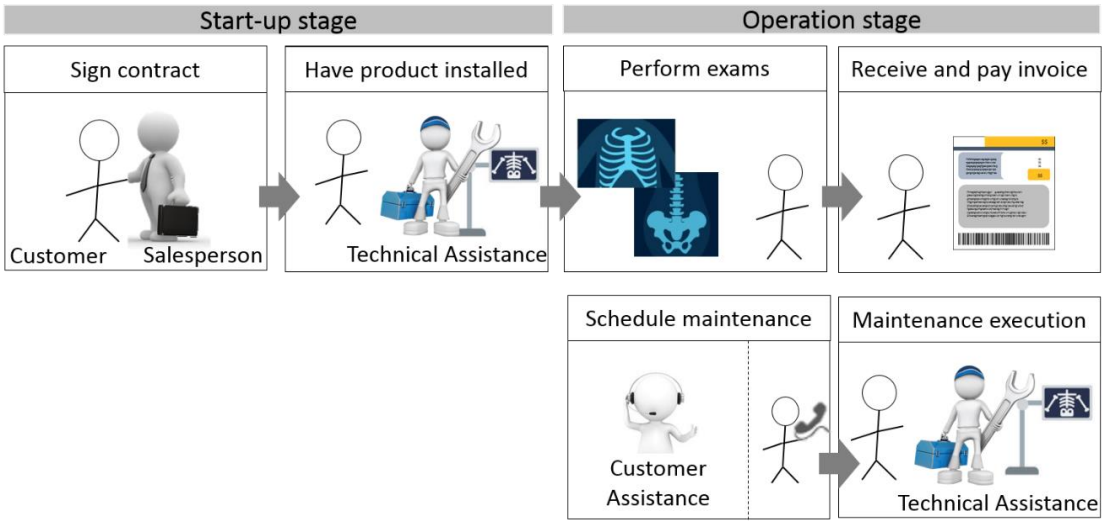


01 Research and Development Department
02 Quality Department
03-05 Current Customers (B2B)
06 Equipment user or operator
07-22 Current users and potential future customers (B2C)
23-24 Doctors specialists in diagnosis
25-27 Help Desk, Technical Assistance
28 Wholesaler
29 Healthcare centers
30 Patient
31 Healthcare insurances
32, 51-56 Universities, technical schools, professors, scientists
33 Secretary
34-35 Sales Representatives and sales team
36 Foreigner buyers
37 Suppliers
38-39 Shareholders and investors
40-42 Industry association
43-44 Banks and financial institutions
45-47 Regulatory agencies
48-50 Competitors
57-58 Potential customers (B2B)

SOURCE: created by the author.

- Storyboard of the services experience of the PSS offer: a representation of the future customers' experience with the PSS offer, describing the relationship and interfaces with the customer and some key internal employees (Figure 42).

Figure 42 – Storyboard of the customer' experience with the PSS offer



SOURCE: created by the author.

3) Develop PSS value proposition

For developing the value proposition, the adapted Bootcamp Bootleg Design Thinking approach proposed by the D.School (PLATTNER, 2010) was applied. It encompassed the following steps[49]:

a. (1) Understand customers and stakeholders to create empathy and identify problems related to the customer's experience with the current product offer (the one selected for the servitization process): more than 13 interviews with different stakeholders (current clients, possible future clients, bank institutions) related to the existing diagnostic imaging equipment were conducted.

b. (2) Define which shortfalls shall be solved as a value of the PSS: 2 customer segments (1 B2B and 1 B2C) were selected as target for the PSS offer.

c. (3) Ideate solutions for the PSS: more than 100 ideas were proposed, from them, 35 more related to services' provision and PSS were selected and prioritized for different moments of implementation.

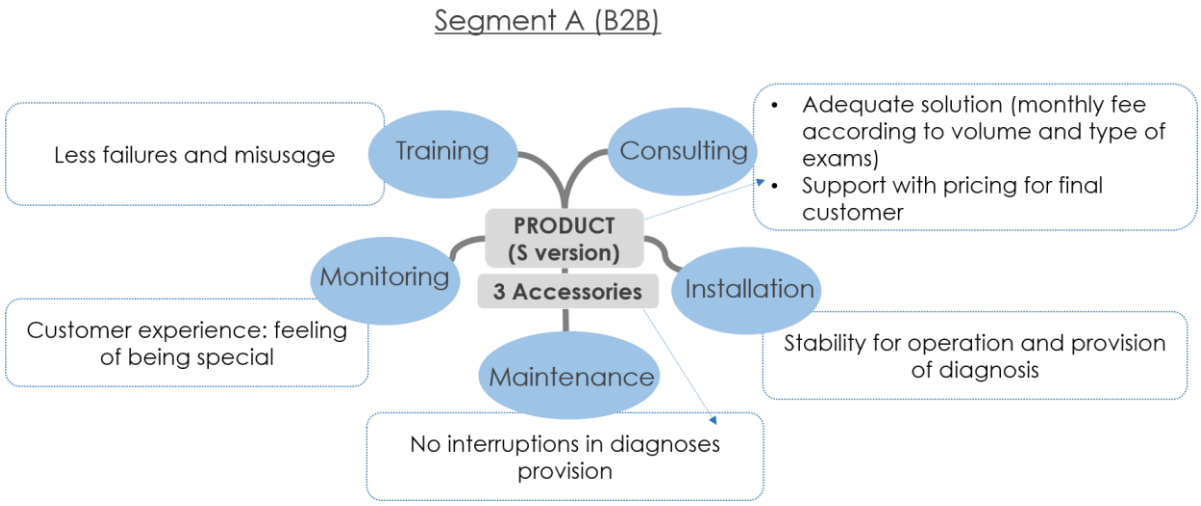
d. (4) Prototype, (5) test with customers, and (6) improve the best PSS solutions according to customer's feedbacks: the prioritized ideas were tested with 6 customers, improved, and generated 2 final value propositions (one for each customer segment).

The main outcomes of this activity for the PSS BPA Development Method were:

- 2 PSS Value Propositions: represented by the description of the bundle of products (in gray boxes) and services (in blue circles) offers and what values (in blue bordered boxes) they deliver to their respective customer segments, as depicted in Figure 43 and Figure 44. Note that the orange boxes and text in Figure 44 indicate the main differences of the Value Proposition B, when compared to Value Proposition A.

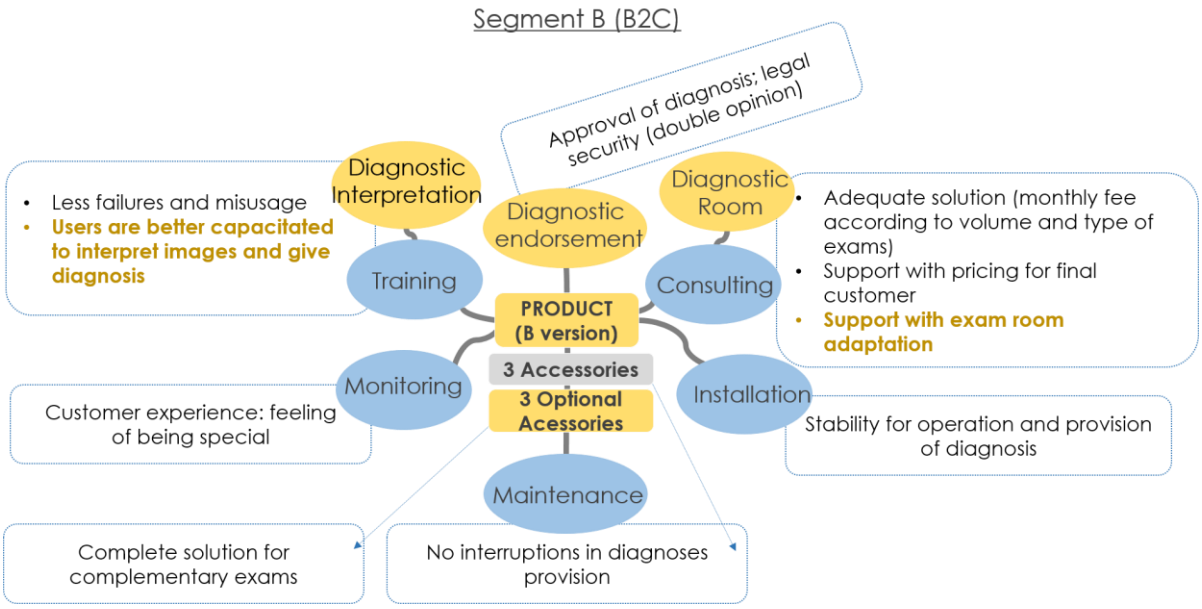
[49] As described in section 1.3, it is not part of the scope of this study discussing details related to the application of the selected Design Thinking approach. For more information about methods and tools, see Pieroni et al. (2016) or Rosa et al. (2016).

Figure 43 - Value Proposition A



SOURCE: created by the author.

Figure 44 - Value Proposition B



SOURCE: created by the author.

4) Activities “Identify PSS processes” and “Align PSS people and systems”

The activities “Identify PSS processes” and “Align PSS people and systems” were conducted during the development of the Initial Business Model with the support of an adapted tool based on the Business Model Canvas (OSTERWALDER; PIGNEUR, 2010) and the PSS Configurator (BARQUET, 2015), as illustrated in Figure 38 (on page 129).

These activities were performed in two workshops. The first workshop, focused on analyzing the “customer segments” and “value proposition”, which were previously determined by the activities “Map potential people” and “Develop PSS value proposition” (see the topics 2 and 3 of this section). After that, in the same workshop, there was time for defining the elements of “customer relationships”, “channels”, and “revenues” dimensions.

The second workshop aimed at detailing the remaining dimensions of the initial business model, which comprise “key processes”, “key resources”, “key partnerships” and “costs”. The identification of elements of these dimensions depends on previous configurations determined during the first workshop.

During the conduction of these two activities (“Identify PSS processes” and “Align PSS people and systems”), some limitations were identified and adjustments were immediately applied. First, the elements of “revenue” and “costs” dimensions of the business model were only superficially defined. Their complete detailing only occurs during the second action research cycle (section 4.3) when the financial assessment for determining the PSS Business Case is performed.

In terms of the activity “Align people and systems”, the initial proposed tool previously presented in Figure 38 (on page 129) was planned to enable the members of the team to associate processes with “key resources” (in terms of functional areas, systems, equipment or materials) and “key partnerships”. However, some modifications in this tool were necessary during the action. The determination of resources, such as ICT systems, materials, equipment or financial resources, could not be anticipated during the Initial Business Model definition. This occurred due to time restrictions, and mainly because those type of information requires knowledge from people of specific functional areas that were not participating in the workshops[50] such as finance, IT, manufacturing. Therefore, the tool was adapted to display only the option of assigning “people” which comprises *functional areas* or *partnerships* (columns 3 to 13 in Table 14). Another modification was that ImageCO chose, at least before assessing the Business Case, an approach of offering the PSS through a subsidiary. Therefore, instead of indicating the responsible functional areas for each process, the researcher

[50] Their participation was highlighted as important for the company’s facilitator; however, they could not attend the sessions since they were involved in other activities.

understood that was more relevant to identify first which company (if the subsidiary or the head office) or partner was responsible for each process.

The main outputs of activities “Identify PSS processes” and “Align PSS people and systems” are respectively:

- Process list: it consists of the set of macroprocesses, processes and subprocesses (see second column of Table 14) for the new subsidiary organization that will provide the PSS. These processes are organized in a hierarchical view (in the first column of Table 14). Besides the processes that are directly related to service delivery, other processes from the PCF structure (indicated by the orange lines in Table 14) also required some adaptation to comply with the PSS context.
- Processes x People matrix: as indicted in Table 14, each process or subprocess was associated to responsible people (columns 3 to 13 in Table 14).

Table 14 - Initial version of ImageCO process list (created by the author/ NOTE: the color code is at the end of the table) (continues)

		People										
Level	**Macroprocess, process and subprocess**	PSS Provider (subsidiary)	Head-office company (acting as supplier)	Product, components and spare parts supplier	Logistics services supplier	Maintenance services supplier	Consulting services supplier (diagnosis endorsement)	Consulting services supplier (training)	Consulting services supplier (maintenance)	Training services supplier	IT services supplier	Partner diagnostics' clinics
CORE PROCESSES (continues)												
1	**Develop Vision and Strategy**											
2	Define the business concept and long-term vision											
2	Develop business strategy											
2	Execute and measure strategic initiatives											
1	**Develop New Product, Services or PSS**											
2	Govern and manage new product/service/PSS development program											
2	Generate and define new product/service/PSS ideas											
2	Develop new products, services, PSS											
1	**Market Product, Services or PSS**											
2	Develop strategy											
2	Develop and manage market plan											
1	**Sell Product, Services or PSS**											
2	Develop and manage sales plan											
2	Sell PSS and elaborate contract											
2	Sell products (after discontinuation of PSS contracts)											
2	Sell services (additional services not included in PSS contract)											
2	Manage PSS contracts (renewal)											
1	**Deliver Physical Products**											
2	Plan and buy spare parts and equipment											
2	Manage warehousing											
2	Manage equipment transportation and delivery											
2	Manage spare parts transportation and delivery											
1	**Provide Services**											
2	**Provide logistics (product transportation and installation)**											
3	Develop logistics service											
3	Manage logistics service											
3	Deliver logistics service											

Table 14 - Initial version of ImageCO process list (created by the author/ NOTE: the color code is at the end of the table) (continuation)

		Actors										
Level	**Macroprocess, process and subprocess**	PSS Provider (subsidiary)	Head-office company (acting as supplier)	Product, components and spare parts supplier	Logistics services supplier	Maintenance services supplier	Consulting services supplier (diagnosis endorsement)	Consulting services supplier (training)	Consulting services supplier (maintenance)	Training services supplier	IT services supplier	Partner diagnostics' clinics
CORE PROCESSES (continuation)												
2	**Provide use training (installation and ramp-up)**											
3	Develop use training service (installation and ramp-up)											
3	Manage use training service (installation and ramp-up)											
3	Deliver use training service (installation and ramp-up)											
2	**Provide qualification training**											
3	Develop qualification training service											
3	Manage qualification training service											
3	Deliver qualification training service											
2	**Provide consulting services (diagnosis endorsement)**											
3	Develop consulting services (diagnosis endorsement)											
3	Manage consulting services (diagnosis endorsement)											
3	Deliver consulting services (diagnosis endorsement)											
2	**Provide corrective maintenance**											
3	Develop corrective maintenance service											
3	Manage corrective maintenance service											
3	Deliver corrective maintenance service											
2	**Provide preventive maintenance**											
3	Develop preventive maintenance service											
3	Manage preventive maintenance service											
3	Deliver preventive maintenance service											
2	**Provide remote up-grade**											
3	Develop remote up-grade service											
3	Manage remote up-grade service											
3	Deliver remote up-grade service											

Table 14 - Initial version of ImageCO process list (created by the author/ NOTE: the color code is at the end of the table) (continuation)

Level	Macroprocess, process and subprocess	Actors										
		PSS Provider (subsidiary)	Head-office company (acting as supplier)	Product, components and spare parts supplier	Logistics services supplier	Maintenance services supplier	Consulting services supplier (diagnosis endorsement)	Consulting services supplier (training)	Consulting services supplier (maintenance)	Training services supplier	IT services supplier	Partner diagnostics' clinics
CORE PROCESSES (conclusion)												
2	**Provide in loco up-grade**											
3	Develop in loco up-grade service											
3	Manage in loco up-grade service											
3	Deliver in loco up-grade service											
2	**Manage PSS disassembly**											
3	Disassemble equipment											
3	Transport equipment (reverse logistics)											
2	**Manage end of life**											
3	Sanitize equipment											
3	Remanufacture equipment											
3	Discard equipment											
2	**Manage Partnerships**											
2	**Manage Customer Service**											
3	Develop strategy											
3	Plan customer touchpoints											
3	Execute customer touchpoints											
3	Monitor customer relationship											
3	Monitor product's use and availability											
3	Assess customer satisfaction											
2	**Provide Technical Assistance**											
3	Develop technical assistance											
3	Manage technical assistance											
3	Deliver technical assistance											

Table 14 - Initial version of ImageCO process list (created by the author/ NOTE: the color code is at the end of the table) (conclusion)

Level	Macroprocess, process and subprocess	Actors										
		PSS Provider (subsidiary)	Head-office company (acting as supplier)	Product, components and spare parts supplier	Logistics services supplier	Maintenance services supplier	Consulting services supplier (diagnosis endorsement)	Consulting services supplier (training)	Consulting services supplier (maintenance)	Training services supplier	IT services supplier	Partner diagnostics' clinics
SUPPORT AND MANAGEMENT PROCESSES												
1	**Develop and Manage Human Capital**											
2	Recruit and retain qualified collaborators											
2	Develop collaborators											
2	Organize and manage knowledge and communication											
1	**Develop and Manage Information Technology**											
2	Manage diagnosis count system											
2	Manage equipment's remote control system											
2	Manage equipment's remote maintenance system											
1	**Manage Financial Resources**											
2	Manage diagnosis count for billing											
2	Manage services billing											
2	Manage recurrent revenues											
1	**Acquire, Construct, and Manage Assets**											
1	**Manage External Relationships**											
2	Manage relationship with government											
2	Manage relationships with industry institutions											
2	Manage legal and regulatory issues											
1	**Manage Risks and Compliance**											
1	**Develop and Manage Business Process (BPM)**											
2	Plan monitoring cycle											
2	Assess processes performance											
2	Improve processes											

Color code:	
	Services' processes incorporated in the PCF
	Processes changed to adapt in the PSS context
ABC	Services support processes

4.2.4 Evaluate action

The activities of the PSS BPA Development Method deployed during the first cycle of the action research enabled the identification of the PSS strategy and main stakeholders, and the generation of an initial view of all necessary processes (first and second hierarchical levels) for the operation of the future PSS of ImageCO during the MOL and EOL phases. This last outcome was obtained very quickly (in the second day of Initial Business Models workshops) and guaranteeing the integration with the company's strategy. It was only possible due to the synergy promoted by combining the BPA approach with other methods of the *PSS Transition Framework.* According to the testimony of one of the collaborators of ImageCO, since for defining the Initial Business Model a previous stage of Value Proposition based on Design Thinking approach was required, preliminary notions of service processes and requirements for operating the MOL and EOL phases of the PSS had already been investigated along with the value discussion. Hence, it was easier to define the complete list of operational processes of the PSS during the Initial Business Model.

Furthermore, the tool applied during the first action research cycle enabled the association of PSS processes with responsible functional areas and potential partnerships. This anticipated the determination of required capabilities (especially related to people) that will enable ImageCO to transform their diagnostic imaging product into PSS. ImageCO's team testimonies show that they were not aware of the complexity of the PSS transition and therefore, this tool helped them understanding the challenges related to organizational transformation and processes changes.

However, some deliverables predicted in the original plan could not be achieved:

- First, as previously described in section 4.2.3, it was not possible to anticipate the detailing of required resources such as systems. Therefore, an activity called "Align PSS systems" remains for being accomplished in the second and third action research cycles.
- A second gap is that the BPA should not be presented only at a macro level, as indicated in business process architecture literature review (section 3.2.4). This is corroborated by Gerosa and Taisch (2009) when they affirm that the particularities of each service are obtained by decomposing "subprocesses" in

"activities"[51]. Hence, a fourth level need to be planned in subsequent cycles of the action research. The further detailing into "activities" may also facilitate the identification of resources' requirements. Therefore, a new activity called "Detail PSS processes" is included in PSS BPA Development Method (illustrated in Figure 46). Since the detailing of processes, may affect the alignment with resources, then a new activity called "Refine PSS people" is also included.

- A third gap is that the end-to-end view of processes could not be clearly established within this tool. For accurately identifying interdependencies between processes, the level of "activities" need to be represented and analyzed in modelling tools, as explained in literature review section 3.2.5.3. This will also be treated in the new added activity "Detail PSS processes".
- Finally, as indicated in Pieroni et al. (2016), since until the conclusion of this report the proposed PSS offer was not yet financially quantified in the *PSS Transition Framework* project, the business processes already identified during the first cycle of the action research may suffer changes that shall be incorporated in the second action research cycle.

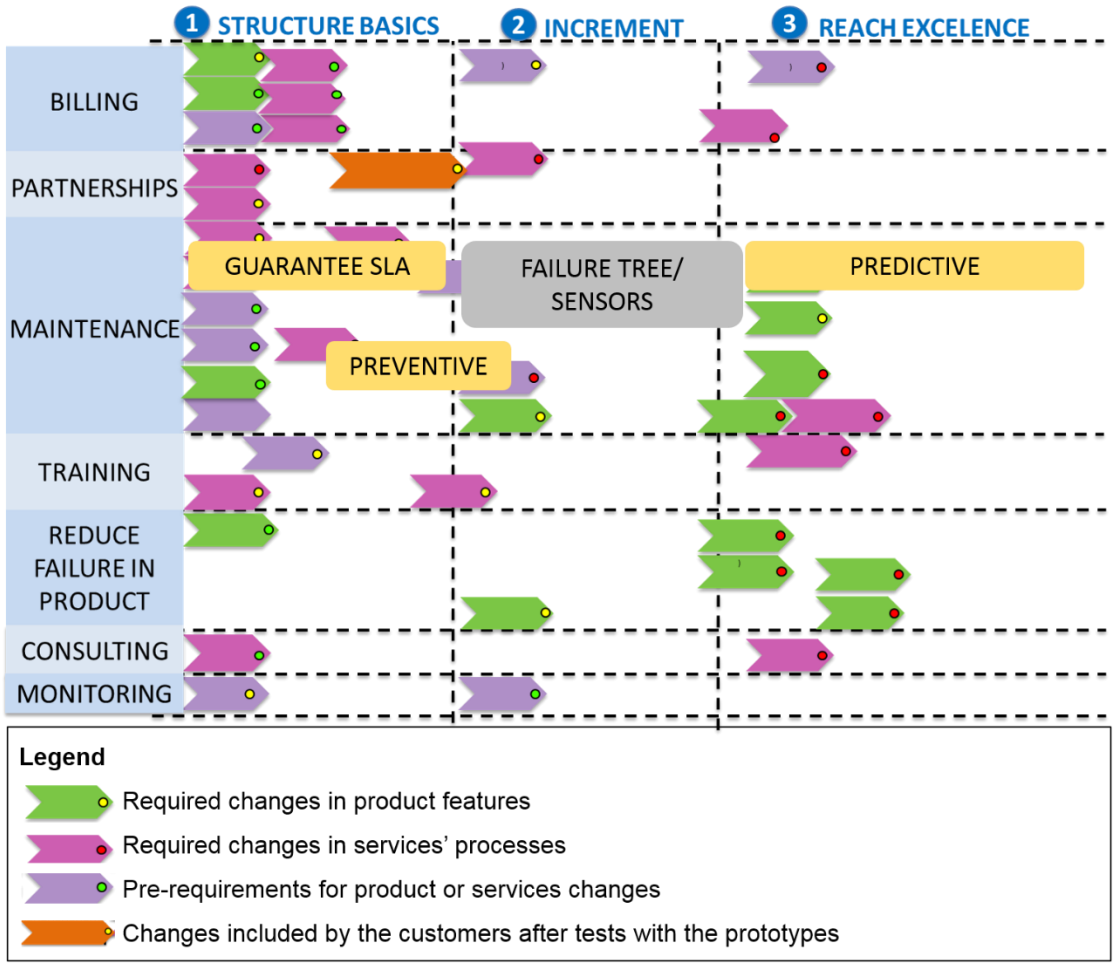
Furthermore, while applying the first activities of the Initial PSS BPA Development Method, new findings arose which indicated the necessity of including new deliverables and activities to the method.

The first finding is that already in the activity "Map potential people", an idea of the service processes were obtained when mapping the relationships with customers as illustrated in the services experience storyboard of Figure 42 (on page 135). Therefore, the initial scope of the activity "Map potential people" was divided in two. The development of the stakeholders' map remained in the scope of activity "Map potential people", while the identification of the relationships with the key stakeholders became scope of a new activity called "Identify PSS services (processes)". This new activity was included in the transitional version of the PSS BPA Development Method. In addition, the activity "Identify PSS processes", was renamed as "Define PSS processes" in order to avoid confusions with the identification of the service-oriented processes aforementioned.

[51] For understanding the terminology considered for the levels of process, consult section 3.2.1.

The second finding was that a great number of ideas of new services and product features were generated during the definition of the Value Proposition. This required relevant changes in processes, and the company had no capabilities for implementing them all at once. It was necessary to prioritize the ideas according to their complexity and relevance regarding the PSS launching. This resulted in an implementation roadmap of the proposed solutions and changes phased in three stages (1-structure the basics of PSS, 2-increment the offer and processes complexity, 3-reach excellence), as illustrated in Figure 45. The blue column on the left describes the main impacted aspects of the company's current BPA. The arrows describe the required changes in terms of product features (green color), services' processes – (in violet color), pre-requirements for product or services changes (in purple), and changes included by the customers after tests with the prototypes (in orange).

Figure 45 - Implementation roadmap



SOURCE: created by the author.

Since the objective here is to show the concept of the implementation roadmap and due to the n.d.a signed, Figure 45 illustrates the evolutionary changes in processes taking only one service as example. Nevertheless, other services were prioritized and considered for the BPA development, as described in section 4.2.3.

The companies' choice at the end of this first cycle was to concentrate effort in defining the PSS BPA only for enabling the first stage of implementation: "Structure the Basics".

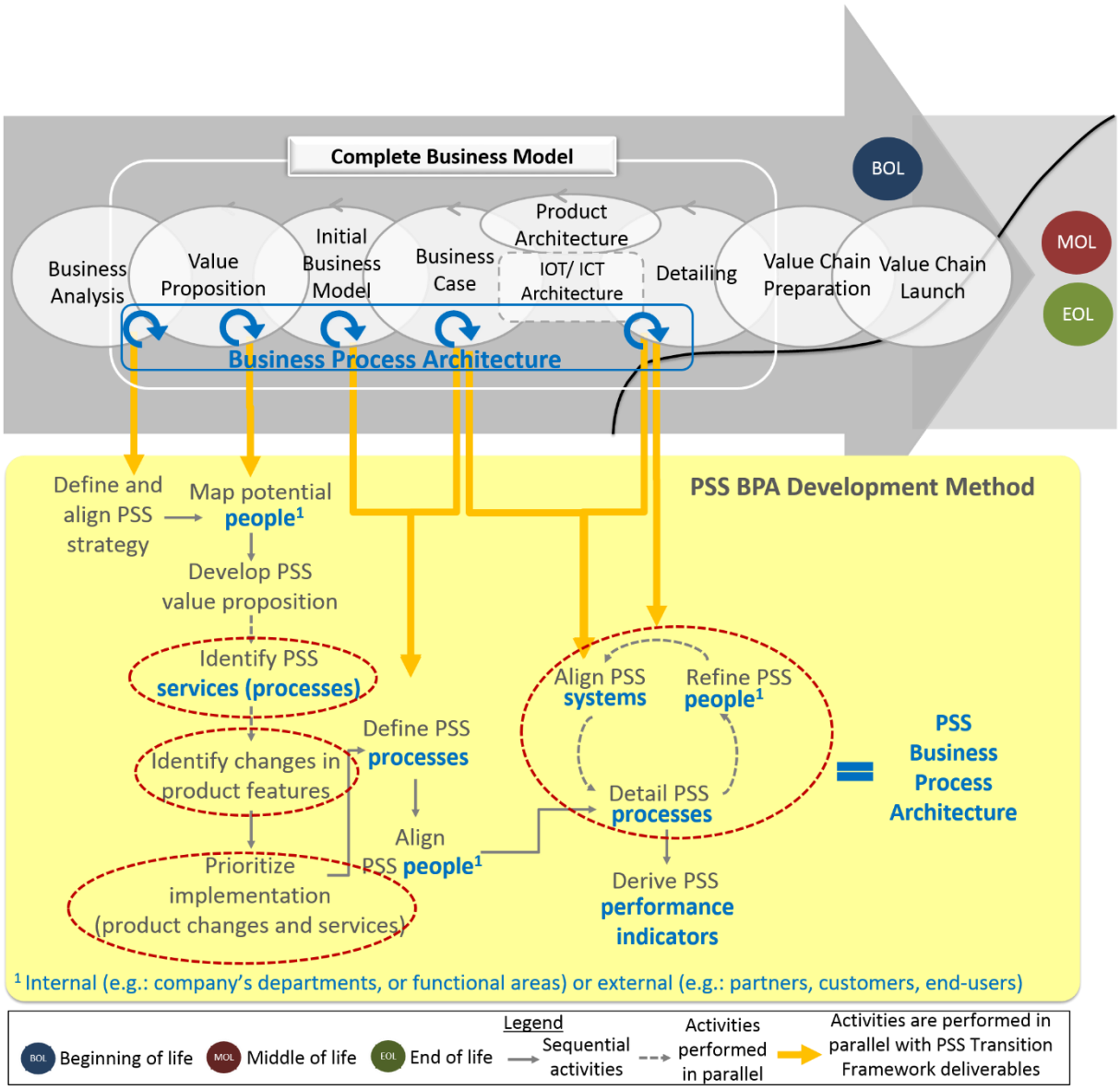
Summing up, a new activity called "Prioritize implementation (product changes and services)" was incorporated in the PSS BPA Development Method, as illustrated in Figure 46. Its deliverable is the implementation roadmap (Figure 45). The inclusion of this activity is in agreement with the business process architecture theory, and is present in BPA methods such as the BPTrend Business Process Architecture (BURLTON, 2015), as described in section 3.2.4.5. The difference of BPTrends approach is that the priotization of changes is the last one, only occurring after the identification of business processes and resources (see activity "Manage Enterpise Process" in Figure 32). On the other hand, in the PSS BPA Development Method the priorization occured before the identification of business processes, when the PSS strategy was being defined, as a consequence of having generated many ideas with the support of Design Thinking. Also, the processes until this moment are directly related to the services provision. Again, this is a benefit of the PSS BPA Development Method only possible due to tits sinergy with other methods from the *PSS Transition Framework.*

As a third finding, required changes on features of the diagnostic imaging product were identified. Those modifications were fundamental to enable the provision of some services' processes in the PSS. In other words, in the context of servitization, the deployment of the PSS BPA may require changes on product features. Therefore, a new activity called "Identify changes in product features" was incorporated in the PSS BPA Development Method, as illustrated in Figure 46. Its deliverable is a list of main required changes on the product features, which also appears in the implementation roadmap indicated in green arrows (Figure 45). For ImageCO three main changes were identified:

- Sensors and system for enabling counting the amount of exams for the billing process (implementation phase 1);

- Remote control for enabling operating and turning the equipment off in case of nonpayment (implementation phase 1);
- Failure indicators (implementation phase 2).

Figure 46 - Transitional PSS BPA Development Method: activities view



SOURCE: created by the author.

Summarizing, the aforementioned modifications in activities (highlighted in dotted red circles in Figure 46) were incorporated in the PSS BPA Development Method. This resulted in a new version of the method, which represents the second deliverable of the third stage of the DRM research framework adopted in this study: *Transitional PSS BPA Development Method (D.3.2)* (Figure 46), as described in methodology section

2.1. This new version of the method was applied and further improved in the following research cycles, as explained in the following sections.

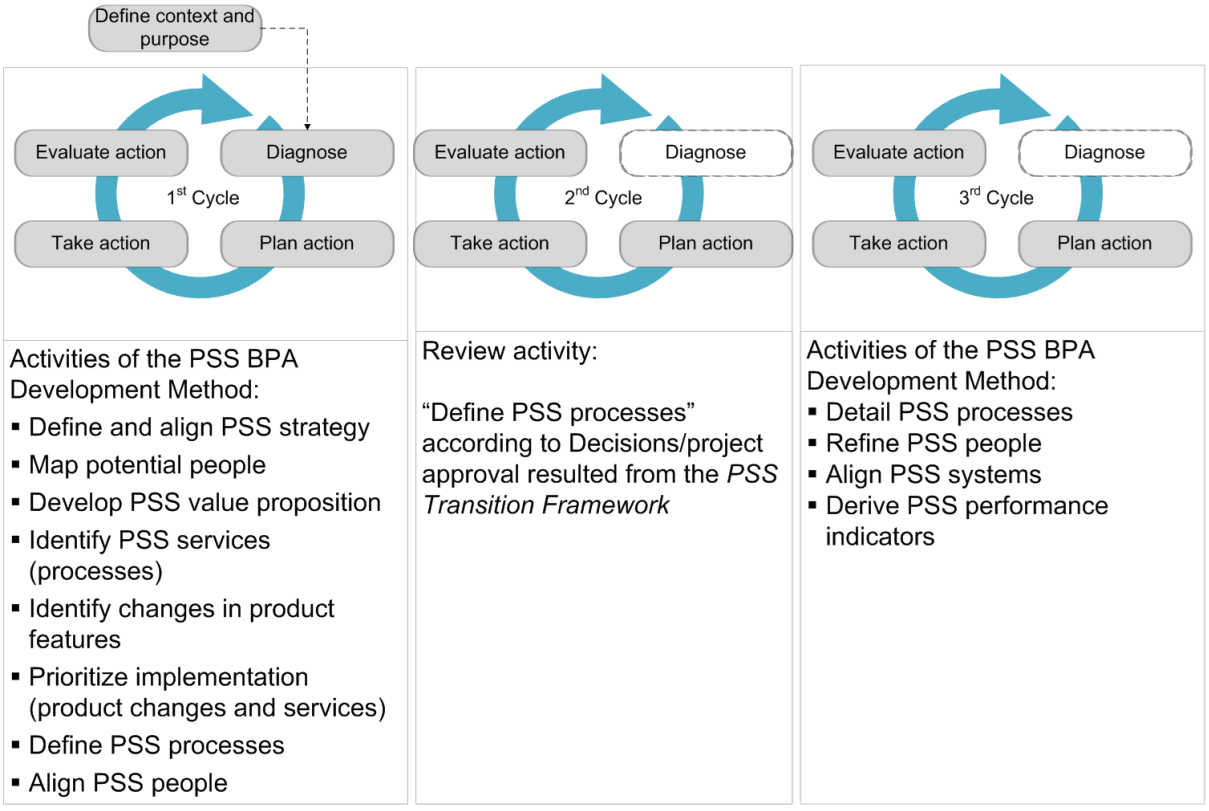
4.3 Second action research cycle

The following sections present the activities performed during this second action research cycle: plan action (section 4.3.1), take action (section 4.3.2), and evaluate action (section 4.3.3). As previously highlighted in the beginning of this chapter, the activity d*iagnose* was not required in this cycle.

4.3.1 Plan Action

The action research plan was reviewed according to the new activities of the Transitional PSS BPA Development Method, as illustrated in Figure 47.

Figure 47 - Updated version of the action research cycles



SOURCE: created by the author.

The second cycle of the action research focused on reassessing the already defined business process structure with new decisions that were taken during the delivery of the Business Case in the *PSS Transition Framework*. Hence, it involved refining the activity "Define PSS processes" (which was previously called "Identify PSS processes"

during the first action research cycle) of the PSS BPA Development Method (Figure 46). This occurred while the Business Case was being developed.

The author of this research participated in the workshops being conducted for defining the Business Case (until the moment of the action research, 4 workshops were realized for defining the Business Case inputs and premises, 2 workshops for refining and validating the business case) with the specific purpose of identifying inputs and premises that could impact processes and resources. Also participated in these workshops: 2 professors, 1 MSc researcher (besides the author of this study), ImageCO project leader, ImageCO Legal and Accounting Manager, ImageCO Finances Manager.

4.3.2 Take Action

This second action research cycle was conducted with the support of a tool applied concomitantly in the *PSS Transition Framework* for defining the Business Case. This tool, adapted from (RODRIGUES; NAPPI; ROZENFELD, 2014), supports the generation of investment assessments for PSS projects[52].

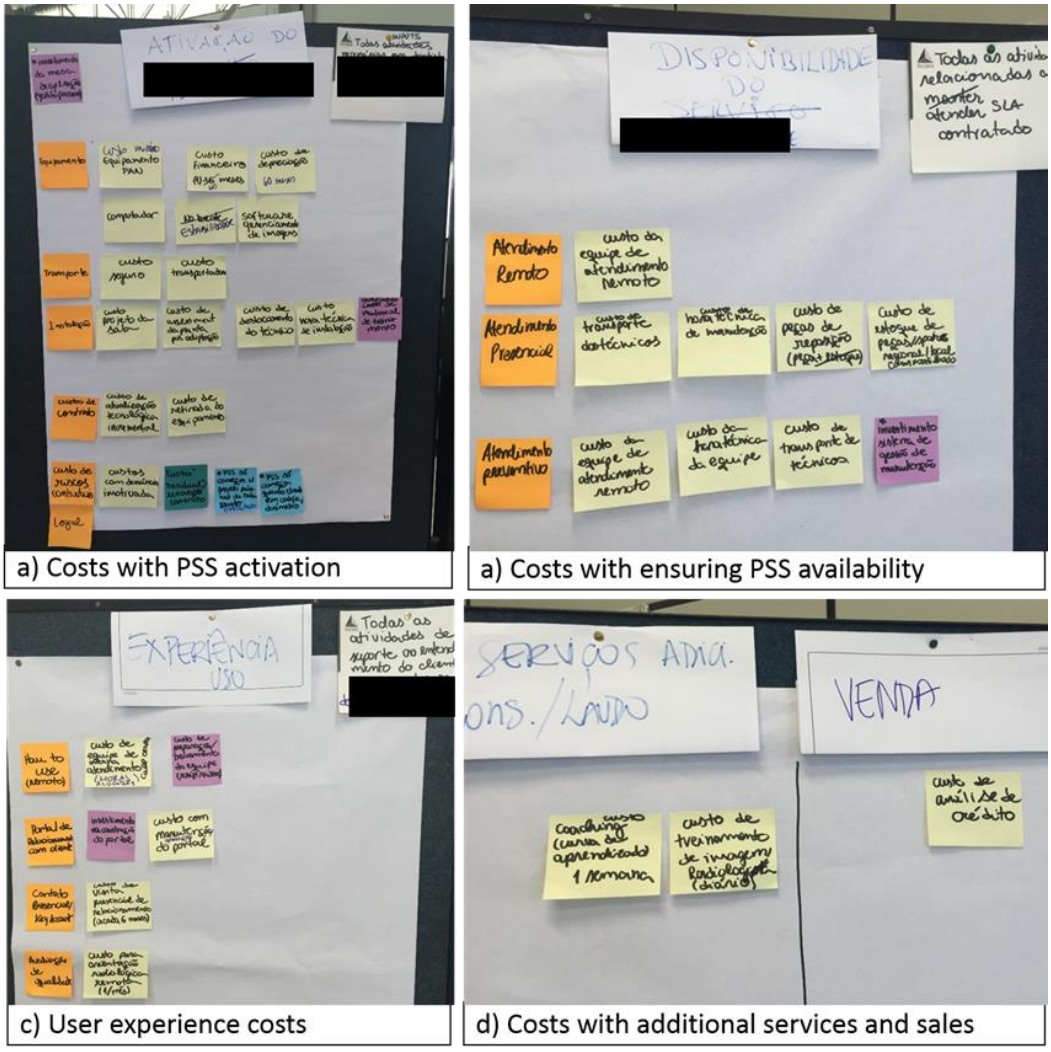
The starting point for applying this tool, consisted in identifying the checklist of business premises (e.g.: planning horizon, sales projection, offer price, investments, discounts, costs, expenditure) in order to feed the tool and determine the cost and revenue structure of ImageCO. This step was very complex and time consuming. Hence, to promote a smooth beginning, a brainstorming session (Figure 48) was conducted in the first workshop in order to identify an initial version of the revenue and cost structure of ImageCO.

After identifying the business premises, ImageCO's project leader was in charge of obtaining the numerical data of each premise with the respective responsible in the company. Then, more three workshops were necessary for inputting and refining the data in the investment analysis tool, and other 2 workshops were conducted with the project team for validating the results. The final validation with the company's directive members (Executive Vice-President, the Sales Director, and the New Business Director) had not yet been conducted until the end of this cycle of the action research.

[52] As described in section 1.3, it is not part of the scope of this study discussing details related to the functioning of the tool applied in the Business Case development. For more information, consult Rodrigues, Nappi, and Rozenfeld (2014).

As expected, some decisions taken during the first workshop in order to define the business premises affected the initial “processes and people matrix” proposed in the first action research cycle. The first decision was that instead of opening a subsidiary company, ImageCO decided to launch the PSS offer inside one of its current business unit as a means of obtaining gains with synergy and investment reduction. This impacted the initial estimative of resources (people) defined during the first action research cycle. The activities that were being executed by the spin-off must be reallocated and distributed for ImageCO’s functional areas. This can be executed by the activity “Refine people” (Figure 46), performed in the third action research cycle (section 4.4).

Figure 48 - Definition of cost and revenue structure



SOURCE: created by the author.

The second decision involved changing the structure of the services' offer in order to compose a better configuration for ImageCO costs' structure. The types of services previously identified in Table 14 (on page 140) at the level of "subprocesses" (level 3) were grouped in five "processes" that represent the PSS life cycle (represented in the first line of Table 15). This influenced the initial "process list" previously identified in the first action research cycle. The new and final version of the complete "process list" is presented in the third action research cycle, in section 4.4.

Table 15 – Changes on ImageCO's process list

PSS life-cycle processes	**Activate PSS Contract**	**Guarantee PSS Availability**	**Provide PSS Use Experience**	**Terminate PSS Contract**	**Provide Additional Services**
Types of services included as activities in each process	• Logistics (product transportation and installation) • Training (installation/ ramp-up)	• Corrective maintenance • Preventive maintenance • Remote up-grade • In loco up-grade	• Customer Service	• PSS disassembly • End of life	• Qualification training • Consulting services (diagnosis endorsement)

SOURCE: created by the author.

Furthermore, the cost estimation for the provision of services, contributed to the identification of an initial Service Level Agreement (Table 16), which is fundamental for the definition of performance indicators in the third action research cycle.

Finally, this second action research cycle also contributed to identifying three new features in terms of IT systems:

(I) a software for enabling counting and transmitting the amount of performed exams to ImageCOs accounting and billing system;

(II) adaptation of ImageCOs accounting system for processing the billing of PSS services;

(III) development of a Web portal for supporting the interface with customers and e-learning.

Table 16 - Premises for the PSS Service Level Agreement

Service process	Availability	Priority	Response	Expected time for solution	Geographic coverage
PSS Contract Activation	5 business days after signing contract	N/A	Scheduled	Scheduled	1 and 2
Availability (Corrective maintenance)	Immediate after activation and customer's call	Critic	1 hours	8 hours	1
		Medium	3 hours	2 days	
		Low	Scheduled	Scheduled	
Availability (Corrective maintenance)	Immediate after activation and customer's call	Critic	1,5 hours	16 hours	2
		Medium	4,5 hours	4 days	
		Low	Scheduled	Scheduled	
Availability (Preventive maintenance)	Immediate after activation and customer's call	N/A	1 in-loco visit per year 2 remote interventions per year	N/A	1 and 2
Availability (Technological up-grade)	All customers: up-grade in software or hardware for quality improvement (do not include new features/change in equipment) Premium customers: up-grade in new functionalities for software	N/A	Scheduled	Scheduled	1 and 2
User experience (call center)	Immediate after activation and customer's call	N/A	Immediate	Immediate	1 and 2
User experience (online web portal)	Immediate after activation	N/A	Immediate	Immediate	1 and 2
User experience (visit Key Account managers)	Immediate after activation	N/A	One visit per semester	N/A	1 and 2
User experience (quality monitoring)	Immediate after activation and customer's call	N/A	Call with a specialist (total of 2 hours per year)	Immediate	1 and 2
Contract termination	Immediate stop of services' offer and removal of equipment in 5 business days	N/A	Scheduled	Scheduled	1 and 2

SOURCE: created by the author.

4.3.3 Evaluate action

The second action research cycle contributed to refining the deliverable of the activity "Define PSS processes". As already expected, it enabled reviewing the initial version of the PSS processes' structure according to decisions taken during the financial assessment of the PSS offer for elaborating the Business Case.

Moreover, it generated inputs for the activities "Align PSS systems" and "Derive performance indicators", which were fully deployed during the third cycle of the action research (section 4.4). The inputs consisted respectively of the requirements for new systems and additional functionalities of existing systems for the PSS operation, and the definition of a Service Level Agreement.

Summing up, this cycle of the action research generated changes in the outcome of the PSS BPA Development Method, which encompassed reviewing the process structure of the specific PSS BPA, as described in the first paragraph. Nevertheless, no improvements were identified in this cycle for the PSS BPA Development Method. This corroborates the importance of only concluding or reviewing the outcomes of the activity "Define PSS processes" after the Business Case is generated.

Despite that, it is important to highlight that although in the case of this specific company the development of the Business Case influenced the definition of the processes of the specific PSS BPA, there may exist cases in which it will not change. That is an aspect that should be further investigated in future researches.

Concluding, the expected outcomes of the second action research cycle were accomplished as planned. The same transitional version of the PSS BPA Development Method previously presented in Figure 46 (on page 148) will be applied in the next action research cycle (section 4.4).

4.4 Third action research cycle

4.4.1 Plan action

The third action research cycle encompassed the following activities of the PSS BPA Development Method: "Detail PSS processes", "Refine PSS people"[53], "Align PSS

[53] The meaning of the process' aspect "people" is an *organizational unit (for the level of processes and subprocesses)* or a *role (for the level of activities),* as explained in literature review section 3.2.5.2.

systems"[54], and "Derive performance indicators", as illustrated in Figure 47 (on page 149). These activities were applied during the *Detailing* phase of the *PSS Transition Framework*.

This cycle required the selection of a modeling language and the previous preparation of a modeling tool by the author of this research, as described below. After that, three workshops were conducted with ImageCO's team for validating and refining the model. It involved the participation of 1 MSc researcher (the author of this study), ImageCO Project Leader (Marketing and Product Manager), and ImageCO IT Manager. The steps and outcomes of these workshops are described in the next section 4.4.2.

Selected business process modeling language (BPML)

As indicated in section 3.2.5.2, the most adequate strategy for representing PSS processes is combining different types of modeling languages. Therefore, the following business process modeling languages (BPMLs) were adopted:

- For the levels of processes and subprocesses: a combination of the Value-added chain (VAC) with the structure of the Services Blueprint for identifying interactions with the customers (as indicated by Becker et al. (2008)).
- For the level of activities: a combination of an extended version of the Event-driven Process Chain (e-EPC) with the structure of the Services Blueprint for identifying interactions with the customers (as indicated by Becker et al. (2008)). The e-EPC was selected, because ImageCO current processes map was based on EPC, so the users were already familiar with the core structure of e-EPC. The adopted extended version of the EPC incorporated the "views" of "systems", "organization and people", and "performance measurement" besides the traditional "functions" and "events". This adaptation is in accordance with previous research from Korherr and List (2007, p. 290).

Selected modeling tool

The modeling tool, called ARPO[55], was used in this cycle in order to enable a graphic representation of processes in vertical (hierarchical) and horizontal (end-to-end)

[54] The meaning of the process' aspect "systems" is a *software* or a *module of a software*, as explained in literature review section 3.2.5.2.
[55] For more information, consult the website http://www.klugsolutions.com/ENG/INDEX.HTML. A free version of the software for training purposes is available in the website.

directions. This software was selected in accordance with the requirements indicated in literature section 3.2.5.3: (I) it is flexible and supports different BPMLs (such as VAC, SIPOC, EPC, BPMN, e-EPC) as well as editing or creating new BPML meta-models; (II) it enables representing 12 “aspects of the process” or “views” (including four related to the business process architecture such as “processes”, “systems”, “organization and people”, and “performance measurement”); (III) the models are accessible to all users since ARPO automatically generates a website with the processes to be published in the company’s intranet; (iv) and finally and most important, the reference model PCF[56] is already modeled as a standard of the software, which significantly reduces the modeling effort.

4.4.2 Take Action

The steps and outcomes of each activity conducted in this cycle are presented below.

1) Detail PSS processes

This activity has two main objectives: improve the representation of the end-to-end view of business processes and further detail the level of activities of the PSS BPA. Note that since it was defined during the second research cycle that ImageCO is going to provide the PSS inside its existing business structure, it is understood that at least in this first moment there is no need for detailing the core (such as product manufacturing), support (such as human resources management), and management (such as product development) processes that the company already realized. However, they should be monitored when the PSS is being implemented (transition from BOL to MOL phase) in order to evaluate if changes are necessary.

As previously mentioned in section 4.4.2, this cycle involved two moments: an internal preparation of the modeling tool by the researcher and validation with ImageCO’s participants.

During the internal preparation of the modeling tool, the levels of “macroprocesses”, “processes” and “subprocesses” that were previously defined during the 1st action research cycle and improved in the 2nd cycle were converted to the selected BPMLs (VAC and e-EPC, as explained in section 4.4.1) in the software ARPO. Then, the “subprocesses” related to the new services were detailed into “activities” based on the

[56] PCF stands for Process Classification Framework. It is the reference model applied in the action research for supporting the definition ImageCO’s BPA. For more information, consult section 4.2.2.1.3.

activities level of PCF and another reference model for PSS as indicated in the last line of Table 17.

In general, the logic in the adaptation of the reference model PCF was changed from the one applied in the first action research cycle, due to improvements suggested after the second action research cycle. Table 17 indicates the changes applied in ImageCO's list of processes by comparing its structure in the first and third action research cycles.

Two changes should be highlighted. First, there was an inversion of the logic at the levels of "processes" and "subprocesses". Previously, the "list of process" was specialized according to the type of service at the "process" level. In the new version, the specialization by type of service only occurs at the level of "subprocesses". Second, the names of the processes were previously associated with a product-oriented perspective, sounding more like product's after-sales services, for example, "deliver installation" and "deliver logistics". During the second action research cycle, it was perceived that from a cost structure perspective it would make more sense to group the services according to the phase of the PSS life cycle (as illustrated in Table 15). Furthermore, this would make more sense for the customer, which is expecting to buy a solution or an experience, and not after-sales services of a product. As an example of this change, the previous services "logistics" and "training" were substituted by the service called "Activate PSS contract".

After the preparation of the tool ARPO, the detailed process model was validated and refined with the Product Manager and the IT Manager in three workshops. The generated process model comprises 14 end-to-end macroprocesses that describe all the functions of the company. As previously explained, only four macroprocesses directly involved in the PSS operation or impacted by it were detailed in four hierarchical levels until the activities' view: "Provide PSS"; "Sell Product, Services and PSS"; "Manufacture and Deliver Products"; and "Manage Finances".

In order to facilitate the navigation through the process model, the software ARPO divides the content of each level (macroprocesses, processes, subprocess or activities) in different screens. Excerpts of some screens - one example of each level of ImageCO's process model[57] - are show in Appendix E.

[57] Only an illustrative example of each level can be shown due to the non-disclosure agreement.

Table 17 – Changes in the structure of ImageCO's list of processes (created by the author)

	1st action research cycle		3nd action research cycle	
Level	**Meaning**	**Representation**	**Meaning**	**Representation**
Macroprocess	Process category	• Deliver Services	Process category	• Provide PSS

Processes	Type of service	• Provide "x" service
		• Provide "y" service
		• Provide "…" service
		• Manage Customer Service
		• Manage Partnerships
		• Manage Technical Assistance
		
		Note: "x" and "y" represent specific process for each service option as indicated in Figure 11.
			Scope of process along PSS Life Cycle	• Plan and manage PSS
				• Deliver PSS (see note)
				  ○ Activate PSS Contract
				  ○ Guarantee Availability
				  ○ Provide use experience
				  ○ Terminate PSS Contract
				  ○ Provide Additional Services
				
				Note*: Deliver PSS* was translated in the sub-bullets according to the scope of each phase of the PSS Life-Cycle. This enabled adapting the processes with the customers' perspective.

Subprocesses	Scope of process along generic service life-cycle	For each type of service ("x", "y", or "…") the following 3 subprocesses were defined: • Develop "x", or "y", or "…" • Manage "x", or "y", or "…" • Deliver "x", or "y", or "…"	Type of service	*Plan and manage PSS* was deployed as follows: • Manage demand→Create resource plan →Enable service delivery • Manage PSS physical assets (equipment) • Manage spare parts • Manage partnerships Each *Deliver PSS* process was deployed as follows: • Program --> Execute --> Manage Deliver "Activate PSS Contract" • Program --> Execute --> Manage Deliver "Guarantee Availability" • Program --> Execute --> Manage Deliver "Provide use experience" • Program --> Execute --> Manage Deliver "Terminate PSS Contract " • Program --> Execute --> Manage Deliver "Provide Additional Services"
Activities	Non applicable		Action	Each subprocess was detailed in activities based on different reference models: Deliver PSS > Activate PSS Contract • 30 activities related to logistics (product transportation and installation) and training (installation/ ramp-up) - (PCF) Deliver PSS > Guarantee Availability • 10 activities related to corrective maintenance - (OSADSKY et al., 2007) • 10 activities related to preventive maintenance - (OSADSKY et al., 2007) • 13 activities related to up-grade - (PCF) Deliver PSS > Provide use experience • 17 activities related to customer service – (PCF) Deliver PSS > Terminate PSS Contract • 10 activities related to PSS disassembly – (PCF) • 4 activities related to end of life (reconditioning) – (PCF) Deliver PSS > Provide Additional Services • 15 activities related to qualification training and consulting services (diagnosis endorsement) – (PCF)

The benefit of using the software ARPO is that it enables the visualization of different "aspects" or "views" of the processes, such as "people", "systems" and "performance measurement". Hence, at the end of this action research cycle, the main deliverable was a specific process model for Image CO, comprising the identification of processes (hierarchical and end-to-end), resources (in terms of people and systems), and performance indicators, which represents the PSS Business Process Architecture of ImageCO's. The required resources in terms of people and systems were indicated at the level of "subprocesses" and "activities", as described in the following topic number 2. The performance indicators were indicated at the level of "subprocesses", as explained later in topic 3 o this section.

2) Refine PSS "people"

The activity "Refine PSS people" occurred during the validation of the process model with the support and experience of the two members of ImageCO.

The process' aspect "people" was allocated to the business processes according to the logic explained in literature review section 3.2.5.2: *organizational units* (which may be internal or external entities) were allocated to the level of "processes" and "subprocesses"; and *role*s were allocated for the "level of activities". In order to enable the allocation of the aspect "people", the Organizational and People Map[58] for ImageCO was defined based on documents provided by ImageCO's Project Leader that described the organizational structure of the company, and inputs obtained in previous action research cycles. For example, during the elaboration of the Business Case, it was identified the necessity of creating two new roles: "PSS sales" and "PSS coordination".

Since ImageCO decided to launch the PSS inside one of its business units, at least until the first year after, the same organizational structure of the company will be used with the addition of two new positions ("PSS Salesperson" and "PSS Coordinator") under the Diagnosis Imaging business unit in order to cope with the requirements of the two new aforementioned *roles*. Nevertheless, the requirements of this aspect should be revised and probably more "people" will be necessary if the estimated growth in sales reaches the projections of the first year.

[58] Due to the non-disclosure agreement signed, this information is not allowed to be published.

3) Align PSS systems

The process' aspect "system" was also allocated to the business processes according to the logic explained in literature review section 3.2.5.2: *software* or *modules of software* were indicated at the level of "activities". With the Product Manager and IT Manager support, each "activity" of the process model was classified as being executed "manually", "semi-automatically, or automatically". For the first case, a responsible *organizational unit* or *role* was allocated to the activity. For the semi-automatic case, a *software* or a *module of a software* and an *organizational unit* or *role* were assigned. In addition, for the last case, a *software* or a *module of a software* was allocated.

New requirements of software and IT infrastructure besides the ones previously identified in the second action research cycle (section 4.3.2) were discovered during this activity:

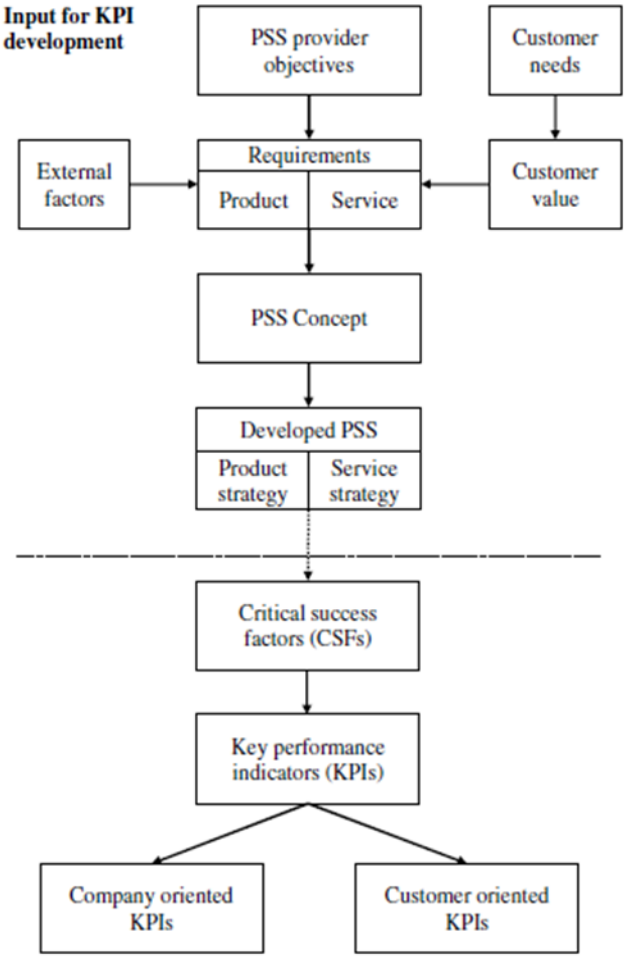
- Changes in the configuration of the Enterprise Resources Planning (ERP) system of ImageCO:
    - Sales and distribution module: changes to enable the operation of selling services by means of a contract, and to enable the fiscal operation of temporary transferring the diagnostic imaging equipment to the customer's site (while the property stays with the provider);
    - Maintenance management module: changes to enable the management of scheduled preventive and corrective maintenances according to each customer's contract;
    - Asset accounting module: changes to enable managing the diagnostic imaging equipment as assets and not inventories like the traditional products for sale, and to enable the billing of PSS contracts;
- Acquisition of training management software (including scheduling, e-learning);
- Installation of two software in the diagnostic imaging equipment to enable the conversion and transferring of image files required for the execution of the additional service of diagnostic endorsement.

At the end, ImageCO participants estimated the financial investments required for the implementation of such changes and updated the Business Case.

4) Derive PSS performance indicators

The activity “Derive PSS performance indicators”, resulted in the list of performance indicators[59], also known as KPIs, which is the acronym for Key Performance Indicators. As already shown in this section, the PCF reference model has limitations in the suggestion of performance indicators, especially for services’ processes. Hence, the deployment of the performance indicators followed an approach similar to the process suggested by Wilberg, Hollauer and Omer (2015, p. 207), which is illustrated in Figure 49.

Figure 49 - Reference approach for the derivation of PSS performance indicators



SOURCE: Wilberg, Hollauer and Omer (2015, p. 207).

The process illustrated in Figure 49 comprises two parts: above the line are the deliverables obtained in the PSS design process, in the bottom are the deliverables obtained in the derivation of the KPIs for the PSS.

[59] Due to the non-disclosure agreement signed, this information is not allowed to be published.

The PSS design deliverables were already obtained in the first action research cycle. For example, the “PSS provider objectives”, the “customers’ values”, the “product and services requirements”, and the “PSS concept” in Figure 49 were obtained when the “Declaration of strategic motivations” and the “Value Proposition” were defined (section 4.2.3). From them, the “critical success factors (CSF)” were deployed, as shown in Table 18.

Then, the selection of performance indicators for satisfying the CSFs was based on consulting other three sources of key performance indicators (KPIs) (MEIER et al., 2013; NAPPI, 2014; WILBERG; HOLLAUER; OMER, 2015), being the first and the last sources specific for the PSS context. Table 18 depicts the list of performance indicators for ImageCO PSS, categorized as “customer oriented KPI” or “Company oriented KPI”, as suggested in Figure 49.

Then, in order to allocate the KPIs in the “process” or “subprocess” levels, it was determined where, i.e. in what process, the expected information to be assessed by the KPI could be obtained.

Finally, a suggestion of metrics[60] for each KPI was defined based on the PSS Service Level Agreement defined during the second action research, as described in section 4.3.2.

[60] The target value expected by the company for each KPI. Since these metrics are specific for each company’s context and objectives, and mainly due to the n.d.a signed, this information was omitted from Table 18.

Table 18 – ImageCO' PSS list of performance indicators (created by the author) (continues)

Services Concepts	Critical Success Factors	Performance Indicator	Type of Performance Indicator	Reference	Calculation
Activate PSS Contract	Ensure quick activation post contract Ensure short stabilization periods Ensure efficiency in technicians capacitation	On time delivery (OTD) [%]	Customer oriented	Meier et al. (2013, p. 102)	"Proportion of delivery processes, which could be completed within the time window promised to the customer."
		Operating time in contract activation [hours]	Customer oriented	Meier et al. (2013, p. 102)	"The operating time needed for the completion of the service task on site, excluding preparatory activities."
		Rescheduling quota [%]	Customer oriented	Meier et al. (2013, p. 102)	"Number of delivery processes that were rescheduled after the customer has been notified or after required resources have been booked in relation to the total number of delivery processes."
		Resource utilization [%]	Customer oriented	Meier et al. (2013, p. 102)	"Resource working time (including operating and travel time) in relation to the overall availability time of the resource."
		Travel time proportion [%]	Customer oriented	Meier et al. (2013, p. 102)	"The average travel time of service technicians in relation to the total working time (including operating and travel time)."
		Incidence of recycling training services	Customer oriented	Based on Nappi (2014, p. 262)	Number of times that a recycling training service was requested per customer
		Number of customer doubts on operation in call center	Customer oriented	Based on Nappi (2014, p. 261)	Amount of doubts in the period
		New customers/ New contracts	Company oriented	Based on Wilberg et al. (2015, p. 206)	Number of new PSS customers Number of new PSS contracts
Guarantee PSS Availability	Ensure high availability of the services	Mean down time (MDT) [days]	Customer oriented	Meier et al. (2013, p. 102)	"Average breakdown time of the equipment within a specific time period, e.g. a year.'
		First time fix rate (FTF) [%]	Customer oriented	Meier et al. (2013, p. 102)	"Proportion of service delivery processes that could be completed at the first attempt."
		Operating time in maintenance [hours]	Customer oriented	Meier et al. (2013, p. 102)	"The operating time needed for the completion of the service task on site, excluding preparatory activities."
		On time delivery (OTD) [%]	Customer oriented	Meier et al. (2013, p. 102)	"Proportion of delivery processes, which could be completed within the time window promised to the customer."
		Mean time to problem solution (MTPS) [hours] Obs.: exclusive to corrective maintenance	Customer oriented	Meier et al. (2013, p. 102)	"Average time from the moment of arrival of the fault report until the moment of function check-out."
		Mean time between failure (MTBF) [days]	Customer oriented	Meier et al. (2013, p. 102)	"Average time between failures."
		Rescheduling quota [%]	Customer oriented	Meier et al. (2013, p. 102)	"Number of delivery processes that were rescheduled after the customer has been notified or after required resources have been booked in relation to the total number of delivery processes."
		Resource utilization [%]	Customer oriented	Meier et al. (2013, p. 102)	"Resource working time (including operating and travel time) in relation to the overall availability time of the resource."
		Travel time proportion [%]	Customer oriented	Meier et al. (2013, p. 102)	"The average travel time of service technicians in relation to the total working time (including operating and travel time)."

Table 18 – ImageCO' PSS list of performance indicators (created by the author) (conclusion)

Services Concepts	Critical Success Factors	Performance Indicator	Type of Performance Indicator	Reference	Calculation
Provide PSS Use Experience	Ensure customer's perception of value	Customer satisfaction	Customer oriented	Nappi (2014, p. 257)	"(Average of the clients' satisfaction level in the period - Average of the clients' satisfaction level in the period before) / Average of the clients' satisfaction level in the period before) *100 "
		Number of customer complains	Customer oriented	Nappi (2014, p. 261)	"Amount of complains in the period"
Terminate PSS Contract	Reduce costs on PSS operation with services	Total cost of service delivery	Company oriented	Meier et al. (2013, p. 102)	"Incurred overall costs for service delivery in PSS."
		Cost of activation Cost with PSS availability Costs with user experience Costs with terminating the contract Costs with remanufacturing	Company oriented	Based on Meier et al. (2013, p. 102)	Incurred costs for each type of service.
		Operating time in remanufacturing	Customer oriented	Based on Meier et al. (2013, p. 102)	The operating time needed for the completion of the equipment reconditioning or remanufacturing.
		Default rate	Company oriented	Included by ImageCO	Sum of overdue installments ($)/ Sum of project revenue ($) for the period
Provide Additional Services	Capture revenue with additional services	Revenue with PSS contracts	Company oriented	Based on Meier et al. (2013, p. 102)	Revenue achieved with PSS contracts.
		Revenue with complementary services	Company oriented	Based on Meier et al. (2013, p. 102)	Revenue achieved with additional services delivery.
		Revenue with extra diagnostic (images)	Company oriented		Revenue achieved with diagnostics (number of images) that surpasses the allowed quota, as agreed in the PSS contract.
		Total cost of complementary service delivery	Company oriented	Meier et al. (2013, p. 102)	Incurred costs for offering complementary services to the PSS.

4.4.3 Evaluate Action

The activities of the PSS BPA Development Method deployed during the third cycle of the action research enabled the definition of a detailed specific process model (until “the activity level”) for the operation of ImageCO’s PSS. This process model presents an end-to-end view and four hierarchical levels (macroprocesses, processes, subprocesses, and activities). Furthermore, it envisions the alignment of processes with resources (in terms of systems and people), and with performance indicators for assuring the monitoring and control of changes according to the PSS and the company’s strategy.

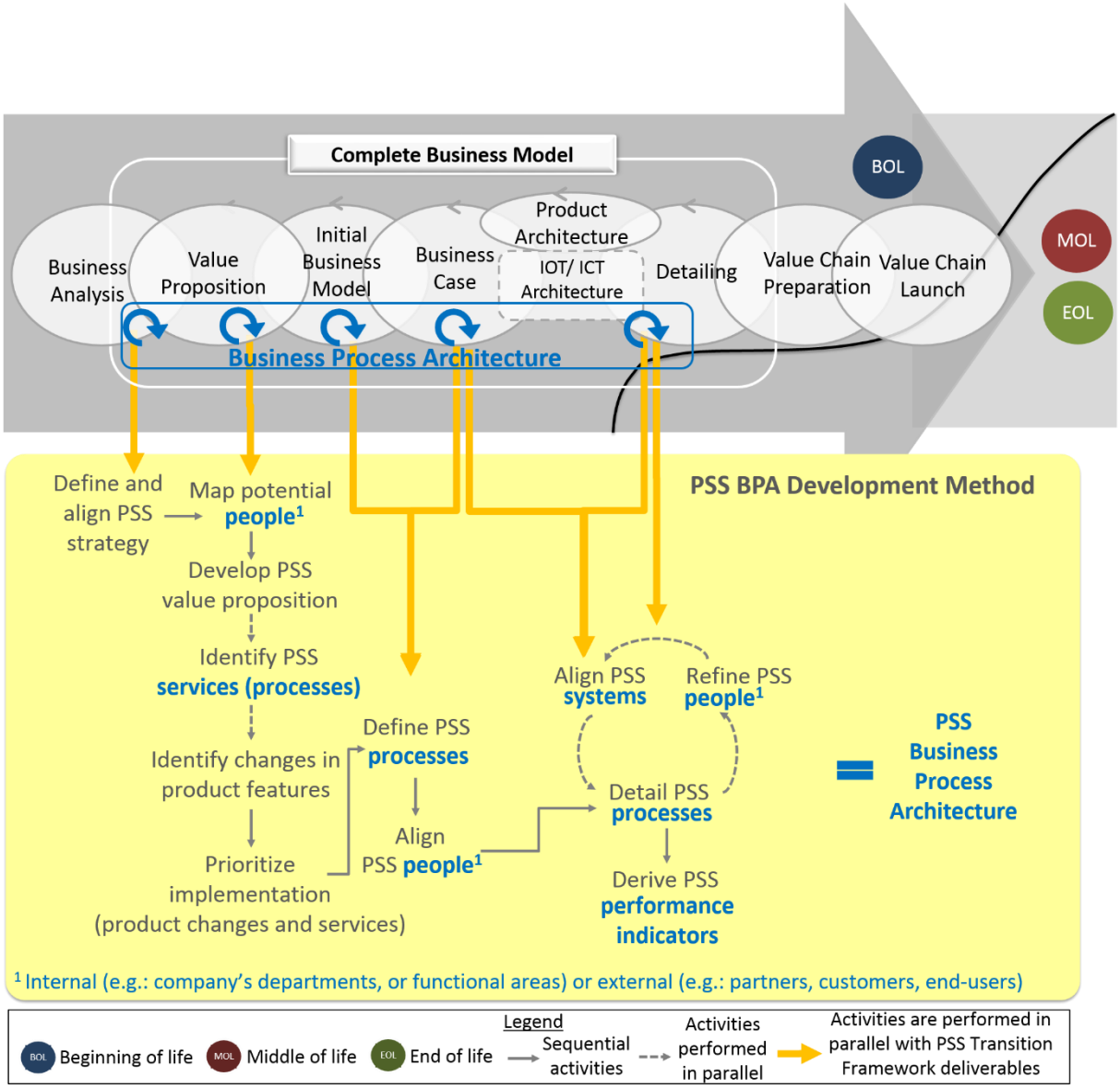
With this, all required elements for the definition of a Business Process Architecture described in section 3.2.4 were obtained. Considering the scope of this research (section 1.3), which was detailing the BPA until the activities level, then the action research is concluded. Nevertheless, the BPA shall be further detailed during the implementation and potentially in the operation phases of the servitization process. Hence, further researches could be conducted to explore that last topic.

Concluding, the third and fourth deliverables of the third stage of the DRM research structure adopted in this study were accomplished: *Final PSS BPA Development Method (D.3.3)* and *Specific PSS BPA (D.3.4)*, as described in methodology section 2.1. The final version of the PSS BPA Development Method is consolidated in the subsequent section 4.5.

4.5 Consolidated version of the PSS BPA Development Method

This section presents the consolidated version of the PSS BPA Development Method (see Figure 50), after the improvements performed during the action research that was conducted in the company ImageCO, as described in sections 4.2.4, 4.3.2, and 4.4.2. Note that, as no modifications were required in the activities of the PSS BPA Development Method after the 3rd cycle of action research, than this consolidated version is the same as the Transitional PSS BPA Development Method, presented in Figure 46 (section 4.2.4, page 148).

Figure 50 - Consolidated version of the PSS BPA Development Method: activities view



SOURCE: created by the author.

The PSS BPA Development Method contains twelve activities that are executed within the *PSS Transition Framework*, concomitantly with other methods and activities of the latter. These twelve activities are:

1) Define and align PSS strategy
2) Map potential people
3) Develop the PSS value proposition
4) Identify PSS services (processes)
5) Identify changes in product features
6) Prioritize implementation (product changes and services)
7) Define PSS processes

8) Align PSS people
9) Detail PSS processes
10) Refine PSS people
11) Align PSS systems
12) Derive PSS performance indicators

The steps, tools and deliverables of the PSS BPA Development Method are detailed in the following sections.

4.5.1 Activity 1: Define and align PSS strategy

This activity consists of understanding the current organizational context of the future PSS provider in order to define the PSS strategy that will guide the definition of the organizational processes for operating the PSS.

An assessment of the current business model of the organization (Business Analysis), based on internal aspects (SWOT analysis) and external aspects (as indicated by the Business Model Generation Methodology, these aspects comprise key regulatory, technological and cultural trends; macro-economic forces; industry forces; and market forces) (OSTERWALDER; PIGNEUR, 2010) should be performed. The assessment may be executed by means of non-directive interviews with different public of the company.

The expected deliverables are:

- Company's current business model;
- Declaration of strategic motivations for offering the PSS (see an example on page 132);
- List of the main challenges for providing the PSS (see an example on page 130).

4.5.2 Activity 2: Map potential people

This activity consists of identifying the potential stakeholders[61] of the future PSS offer, which may become the "people[62]" related to the PSS operational processes in the BPA.

[61] Stakeholder is a term commonly used in project management field with the meaning of "an individual, group, or organization who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" (PMI, 2013, p. 562). The development and launching of a PSS offer is considered a project for the organization. Therefore, the term stakeholders applies in this context.

[62] The term "People" is usually applied in business process management (BPM) field, specifically in modeling. In this study, "People" is considered as an *organizational unit*, which can be internal or external (such as customers, partners), or a *role* that performs or is involved in the execution of a specific

It is a pre-requisite for performing the activity “Develop PSS value proposition” (section 4.5.3).

It is executed in a brainstorming session with members of different functional areas in the organization (at least Marketing, Sales, After Sales, and Engineering). The objective of the brainstorming session is identifying all the stakeholders that are currently directly or indirectly involved with the product component of the PSS offer (since in servitization the starting point for developing the PSS is the existing product component) or have the potential of being involved with the PSS. Not only the potential PSS stakeholders but also the stakeholders involved with the current product are assessed, since the final PSS stakeholders will only be confirmed after the complete development of the value proposition (see section 4.5.3). Finally, the identified stakeholders should be classified in a map (similar to the one in Figure 41 on page 135) according to their level of interface with the PSS product component.

The expected deliverable is:

- Stakeholders map (see an example in Figure 41 on page 135).

4.5.3 Activity 3: Develop PSS value proposition

This activity consists of determining the target customer segments for the PSS, and the bundle of products and services that composes the PSS offer as well as what values they deliver to the target customer segments considering stakeholders’ requirements, which is the value proposition.

For developing the value proposition, six main steps should be performed:

1) Understand current customers and stakeholders related to the product component of the PSS as well as the potential PSS stakeholders (previously identified in the stakeholders map indicated in section 4.5.2) through interviews.

   The objective of this step is to create empathy and identify problems related to the customer’s experience with the current product offer (which is the one

process, subprocess, or activity. Therefore, some stakeholders of the PSS offer development project become “People” involved in the PSS operational processes. Although the activity 2 could be called “Map potential stakeholders”, since the PSS BPA Development Method is inserted in the modeling context, the term “People” is adopted.

selected for the servitization process) and insights of value opportunities[63] to satisfy current or potential stakeholders' additional needs.

2) Determine the target customer segment (or segments) and other key PSS stakeholders and define which value opportunities should be considered in the PSS solution.

3) Ideate PSS solutions for the value opportunities and target PSS customer segments.

4) Create low-fidelity prototypes.

   Different types of prototypes, varying from low-fidelity to high-fidelity, may be generated according to the phase of PSS development. Since this activity of developing the value proposition occurs in the early PSS development stage, and the prototype has the intention of externalizing an idea of the PSS concept when not much information and details are available, low-resolution design prototypes are suitable (GENGNAGEL; NAGY; STARK, 2016, p. 5). Prototyping is considered a gap in PSS literature (EXNER et al., 2014, p. 69). In the action research described in this study, service-oriented prototype techniques (i.e.: storyboards) were applied. Nevertheless, they present limitations, as the combination with the product aspects was not properly covered. Specific techniques for PSS prototyping combining service and product aspects were recently developed by research community and are still being tested (EXNER et al., 2014, p. 70).

5) Test the prototypes with potential PSS customers and other key stakeholders.

6) Improve the description of the best PSS solutions according to the customers' and stakeholder's feedbacks.

The expected deliverables are:

- One or more PSS Value Proposition(s) (see examples in Figure 43 and Figure 44 on page 137).

[63] Value opportunities include "new opportunities of additional value creation and capture through new activities and relationships, value for new stakeholders, or new forms of value" (YANG; RANA; EVANS, 2013, p. 4).

4.5.4 Activity 4: Identify PSS services (processes)

This activity consists of identifying the relationships of PSS key stakeholders, especially customers and end-users, with the PSS offer. The representation of such relationships describes the services experience or services processes[64] of the PSS.

It is conducted partly in parallel with the delivery of the Value Proposition of the *PSS Transition Framework*, and with the activity "Develop PSS value proposition" (section 4.5.3).

It consists of selecting the key stakeholders, which are the ones that will be more involved with or impacted by the PSS offer (such as customers, end-users, and internal employees), and representing their relationships with the PSS offer in storyboards (see Figure 40). These relationships (representing the services processes of the PSS) are determined based on information obtained during the interviews with customers performed in the activity "4: Develop PSS value proposition" (section 4.5.3), and based on the PSS value proposition.

The expected deliverable is:

- Storyboard of the services experience of the PSS offer (see an example in Figure 42 on page 135).

4.5.5 Activity 5: Identify changes in product features

This activity involves identifying new features or modifications in existing features of the physical product component due to new requirements of the customers, or for enabling the provision of certain PSS services defined in the value proposition (section 4.5.3).

It is conducted partly in parallel with the delivery of the Value Proposition of the *PSS Transition Framework*, and with the activity "4: Develop PSS value proposition" (section 4.5.3). Similarly to what happens with the changes in service-oriented processes (see section 4.5.4), the changes on the product features are determined based on information obtained during the interviews performed with customers and

[64] As previously explained in literature review section 3.1.7 on page 71, the service's concept is translated into processes. That is a consequence of the intangible nature of services that unlike products cannot be represented through sketches of physical pieces, being represented as a sequence of actions (JOHNE; STOREY, 1998, p. 188). Hence, services experience and services processes are equivalent.

other key stakeholders in the activity “4: Develop PSS value proposition” (section 4.5.3.3) and also based on the PSS value proposition.

The expected deliverable is:

- List of main required changes on the product features (see an example on page 143).

4.5.6 Activity 6: Prioritize implementation (product changes and services)

This activity involves estimating and prioritizing the changes required for enabling the services-oriented processes identified in activity “4: Identify PSS services (processes)” (section 4.5.4).

It is conducted in a brainstorming session with a multifunctional team of specialists of the company (at least Marketing, Sales, After Sales, and Engineering). The aim is translating the required services previously identified in section 4.5.4 in changes on the service-oriented processes. These changes may comprise the creation of new processes or modifications of already existing processes. After that, the changes on service-oriented processes are ranked in different phases of implementation according to their complexity and relevance for the PSS launching.

The expected deliverable is:

- PSS implementation roadmap (see an example in Figure 45 on page 146).

  This roadmap comprises not only the changes on the service-oriented processes, but also the required changes in product features previously described in section 4.5.5.

4.5.7 Activity 7: Define PSS processes

This activity aims to define the list of all the core (such as product manufacturing, services provision), management and support processes required for the operation of the PSS. It involves the service-oriented processes, which were previously identified in activity “4: Identify PSS services (processes)” (section 4.5.4), and other processes beyond the ones related to services.

It is performed during the development of the Initial Business Model and the Business Case in the *PSS Transition Framework*.

The identification of PSS processes occur in three steps:

1) Select one business process reference model or a combination of different reference models for guiding the process identification.

   This reference model may be embedded in the initial business model tool. The selection of the most appropriate reference model or the most appropriate combination may be supported by the Business Process Reference Model Catalogue (Appendix C) and the Comparative Analysis of Business Process Reference Models for PSS (presented in section 4.2.2.1.3). As already indicated in the aforementioned section, according to the analysis conducted in this study, the Process Classification Framework (PCF) when adapted for PSS context was identified as the most appropriate for the PSS context. Nevertheless, other more appropriate specific business process reference models for PSS may emerge in the future. Moreover, the company's reality may require other reference models that encompass certain specificities, and therefore, this first step is fundamental and should not be skipped.

2) Develop the to-be PSS business model, which may occur in one or more workshops involving a multifunctional team of the company (at least Marketing, Sales, After Sales, and Engineering).

   An adapted tool based on the Business Model Canvas (OSTERWALDER; PIGNEUR, 2010) and the PSS Configurator (BARQUET, 2015) is applied to support the business model development (see example in Figure 38 on page 129). Since the business model dimensions "customer segments" and "value proposition" were outputs of the activity "3: Develop PSS value proposition", then the focus of the workshops is on defining the remaining dimensions of the business model: "customer relationships", "channels", "revenues", "key processes", "key resources", "key partnerships" and "costs". The main interest of this activity is the definition of the dimension "key processes", which generate an initial list of all processes required for the PSS provision and operation at a conceptual level of abstraction (until the level of subprocesses)[65]. In this work, "key processes" are interpreted as business processes, which include all set of core, management, and support processes of an organization. Hence, the representation of the processes for enabling the operationalization of the

[65] In this study, the levels before subprocesses comprise "macroprocesses" and "processes"; however, this may vary according to the selected business process reference model.

dimensions “customer relationships” and “channels” (which describe respectively the company’s strategy for relating to its customers and the strategy for communicating, selling and delivering the value proposition) are considered in the dimension “key processes”.

3) Review the initial list of processes according to the decisions documented in the Business Case (which is delivered after the business model is financially assessed), such as the estimation of a Service Level Agreement (Table 16).

   In Figure 50, the activity “Define PSS processes” receives a yellow arrow with two origins coming from the *PSS Transition Framework.* One comes from the Initial Business Model and the other from the Business Case. This means that this activity 7 is only concluded after the completion of both aforementioned deliverables from the servitization process. The left side of the arrow comprises the steps 1 and 2 described above, and the right side of the arrow comprises step 3.

The expected deliverables are:

- Initial processes list (until subprocesses levels) including all core, management, and support processes of the PSS business (see example in Table 14 on page 140).
- Initial PSS Service Level Agreement (see example in Table 16 on page 153).

4.5.8 Activity 8: Align PSS people

This activity involves defining required people (organizational unit or role) for enabling (which may include executing, approving, being informed of) the processes of the PSS business.

It is conducted in parallel with the creation of the Initial Business Model and after the activity “7: Define PSS processes”, described in the previous section.

It involves the following steps:

1) Assign responsible “people” represented by an *organizational unit*[66], which can be internal (e.g.: company’s departments, or functional areas) or external (e.g.: PSS customers, end users, and partners) to the “processes” or “subprocesses”

[66] An *organizational unit* represents a group of *people* and may be internal (such as a certain department or functional area within the organization) or external (such as a partner or customer).

that they are responsible for in the processes list generated in the previous activity (see section 4.5.77)). This results in a matrix format table relating Processes vs. People.

2) Similarly to what happened with activity 7 (see section 4.5.7), review the Processes vs. People matrix after the decisions taken during the financial assessment of the PSS (Business Case).

The expected deliverable is:

- Processes vs. People matrix (see example in Table 14 on page 140).

4.5.9 Activity 9: Detail PSS processes

This activity focuses on further detailing the processes list obtained in activity "7: Define PSS processes" until the level of "activities" as well as graphically representing the end-to-end view of the processes. To do that, the following steps are necessary:

1) Select a modeling language and a modeling tool according to the requirements of each organization. Some guidelines to support these decisions are presented in sections 3.2.5.2 and 3.2.5.3.

2) Model the "macroprocesses", "processes", and "subprocesses" that were already defined in activity 7 (see section 4.5.7) with the selected modeling tool.

3) Deploy the "subprocesses" in "activities", which may occur in working meetings with members of the company from different functional areas (at least IT, Services Delivery or After Sales).

   This step may be oriented by adapting one or more Business Process Reference Models to the PSS context. A Business Process Reference Model Catalogue (Appendix C) and a Comparative Analysis of Business Process Reference Models for PSS (presented in section 4.2.2.1.3) may be consulted to support the selection and adaptation of reference models.

The expected deliverable is:

- Detailed process model for the PSS business (see examples on Appendix E).

4.5.10 Activity 10: Refine PSS People

This activity consists of updating the assignment of responsible people for each process after they were further detailed until the "level of activities".

It occurs in parallel with the process modeling performed in the previous activity “9: Detail PSS processes”, and involves the following steps:

1) In order to enable the assignment of the aspect “people” in the process model, define the Organizational and People Map of the PSS provider, which may rely on organizational structure documents and inputs (such as the necessity of new roles) obtained in previous activities of the PSS BPA Development Method.

   The Organizational and People Map should be represented by means of *organizational units*[67] and *roles*[68].

2) Review the “people” previously defined in activity “8: Align PSS people” according to the changes applied in the process model during the activity “9: Detail PSS processes”.

3) Allocate *organizational units* to the level of “processes” and “subprocesses”, and *role*s to the “level of activities” in the process model.

The expected deliverables are:

- Detailed process model with “people” view (see example on Appendix E).
- A list of extra “roles” or “positions” required for enabling the PSS operation.

4.5.11 Activity 11: Align PSS systems

This activity consists of identifying and allocating the aspect “systems” to each business process in order to satisfy the requirement of new IT systems features. This aspect “systems” may be represented as *software* or *modules of software.*

It receives inputs from the PSS Business Case and occurs in parallel with the process modeling performed in the previous activity “9: Detail PSS processes”. It comprises the following steps:

1) Re-collect new systems’ features that were previously estimated during the servitization process for composing the Business Case (see example in section 4.3.1).

2) Classify each “activity” of the process model as being executed “manually”, “semi-automatically, or automatically”.

[67] Consult footnote 66 on page 175.
[68] A *role* is a function that a *person* performs in the company.

3) For the semi-automatic and automatic activities, allocate the aspect “system” in terms of *software* or *modules of software* to the level of “activities”.
4) Identify requirements of new software or configuration of existing software after the allocation performed in step 3.
5) Estimate the necessary investment with the new requirements identified in step 4 and update the Business Case.

The expected deliverables are:

- Detailed process model with “systems” view (see example on Appendix E).
- An estimative of required IT Investments (in terms of software acquisition or configurations in existing ones) for the PSS operation. This information should be used to update the servitization Business Case.

4.5.12 Activity 12: Derive PSS performance indicators

This activity aims to determine the PSS performance indicators for enabling the monitoring and control of the PSS business processes. It occurs after the modeling of processes performed in activity “9: Detail PSS processes”.

It may be performed in working meetings involving participants from different functional areas inside the company (at least Marketing, Sales, After Sales, and Finances).

The following steps are required:

1) Derive Critical Success Factors (CSF) for the PSS from the “PSS provider objectives”, the “customers’ values”, the “product and services requirements”, and the “PSS concept” obtained in the previous activities 1 and 3.
2) Select performance indicators for satisfying the CSFs.

   Potential sources of Key Performance Indicators indicated in section 4.4.2 may be used to support the selection.
3) Define metrics (objectives) for each performance indicator of the PSS.

   The determination of these metrics may be oriented to two perspectives: customers’ and provider’s perspectives. Concerning the customers’ perspective, a reference to guide the definition of the objectives is the PSS Service Level Agreement defined in activity “7: Identify PSS processes”. As for the provider’s perspective, since in servitization the companies’ normally have

no previous experience with PSS, a possible guide for supporting the definition of the KPI metrics would be benchmarking with experts or experienced company's in PSS provision.

4) Allocate the aspect "performance indicators" to the level of "processes" or "subprocesses" in the process model.

The expected deliverables are:

- Detailed process model with "performance indicators" view (see example on Appendix E) for the PSS (according to the Service Level Agreement).
- List of performance indicators containing the indicator name, the calculation formula, the target metric (objectives), and the indication of where (in terms of "processes" and "subprocesess") the indicators are measured and what process they asses (see example in Table 18 on page 163).

4.6 Initial Descriptive Study II: assessment of usability and applicability of PSS BPA Development Method

This section summarizes the outcomes of the fourth research stage of DRM. As already indicated in methodology section 2.2.4, the objective of this activity is preparing the proposed PSS BPA Development Method for the further activities, such as the conduction of case studies, which aim at generalization (out of the scope of this work). It contributes with the two final deliverables of this research, which are an *Indication of the applicability and usability of the PSS BPA Development Method (D.4.1),* and an *Indication of the issues that require detailed evaluation and a suggestion for a full Evaluation Plan (D.4.2)*.

Concerning the first deliverable, the preliminary assessment of the potential of usability and applicability of the method was obtained by means of feedbacks from the ImageCO participants (marked as "F" before the statements) collected at the end of each action research cycle. These feedbacks reflect the self-experience of the participants, which in this case represent the end-users of the method, in their own-words. Hence, although they do not strictly follow traditional techniques for measuring usability, they are suitable for this purpose of an initial assessment (HEDEGAARD; SIMONSEN, 2013, p. 2089).

Some excerpts of those feedbacks are presented as follows:

First action research cycle

- F1 - [Marketing and Product Manager]: “I also liked the method, it is very practical. When you develop a business plan there are many things for seeing, but this method (the application of activity “Define PSS processes”) enables envisioning all business aspects in only one canvas. Additionally, having elements of some dimensions (“value proposition” and “customer segments”) already pre-defined from previous phases, saved time and facilitated the conduction. In my opinion, I think that we would be still discussing customer segments if we had not conducted the previous activity of “Develop PSS Value Proposition”. In addition, in my opinion we would have not achieved the same results if we had not visited customers. We obtained information that we did not have (such as the fact that only a minority of end users require ratifications on diagnostics) and confirmed suspicions.”
- F2 - [Engineering Manager]: “I think that we were conducted by the method and it is well defined so far. Regarding the duration of the workshops, I think they were compact and worked well.”

Third action research cycle

- F3 - [Marketing and Product Manager]: “I cannot think of developing a new PSS without applying this method.”
- F4 - [Marketing and Product Manager]: “Previously, we used to think of a new business model, but only focusing on a pure rental of the equipment. Today, we are able to understand and envision a solution that enables more gains and delivers more value to the customer”.

From the feedbacks F1 and F2, it is possible to infer that the “usability” of the PSS BPA Development Method is satisfactory. As for the “applicability”, the feedbacks F1, F2, and F4 were very positive, indicating the potential for following with the assessment of the PSS BPA Development Method in a comprehensive study. This comprehensive study involves assessing the applicability of the method by conducting multiple case studies in different context in order to enable the confirmation of patterns and generalization of results. Moreover, the usability should also be confirmed with more robust methods for each situation.

As already indicated in the methodology section 2.1, the aforementioned analysis performed in this section presents limitations. It is an initial assessment of the method that was conducted within the action research cycles concomitantly with the *evaluation* steps. This initial assessment only provides an indication of the potential usability and applicability of the PSS BPA Development Method. Nevertheless, the confirmation of patterns and generalization of the applicability and usability of the method should be performed in further researches in a comprehensive study. To support the conduction of this comprehensive study in future researches, an *Indication of the issues that require detailed evaluation and a suggestion for a full Evaluation Plan (D.4.2)* are presented as follows:

- One improvement for the method was suggested: the development of a tool or procedure that makes the connection of the Business Case definitions with the detailed process model more smoothly. This improvement may be incorporated in the method in future researches.
- A full plan for the comprehensive study could comprise case studies in companies from other sectors, but with the same profile as ImageCO, in other words, companies aiming to provide use-oriented PSS based on existing offer of products. After that, new case studies could be carried for validating the applicability of the method in other types of PSS, such as the result-oriented types.

Since the empirical method enabled the researcher experiencing a real case of servitization while it was happening, findings about the servitization processes and the organizational transformations are discussed in the subsequent chapter.

5 Final considerations

The objective of this chapter is to present the concluding remarks of this study. It is organized in four sections. Section 5.1 discusses the application of action research in this work and presents recommendations for the application of action research in future PSS research. Section 5.2 summarizes main insights about the servitization process performed in the action research. In section 5.3 the conclusions of the research are presented. Finally, section 5.4 points out the limitations of this work and future research opportunities.

5.1 Final considerations and recommendations about the action research

This section aims to discuss if the application of the action research method satisfied the purposes of this study, and to recommend improvements for future applications of this method. Hence, it highlights positive aspects and potentials of improvement based on the researcher's self-reflections and learning process.

As described in sections 4.2, 4.3 and 4.4, two versions of the PSS BPA Development Method were proposed as outcomes of the application of the action research: the Initial PSS BPA Development Method and the Transitional/Final PSS BPA Development Method. This experience enables answering the research question from section 1.2, which was "How should existing methods from BPM field for defining BPA be applied during the servitization process to support manufacturing companies in defining their business processes for the operation (MOL and EOL phases) of a PSS?"

The proposition of the PSS BPA Development Method, which is comprised in a broader servitization process model called *PSS Transition Framework*, was based on some activities of a traditional BPA method called BPTrends Business Process Architecture from Burlton (2015). With the action research, it was possible to empirically test different combinations of activities from the BPTrends Business Process Architecture with activities from other methods being applied in the *PSS Transition Framework* in order to propose an appropriate version of a BPA method for the PSS context.

Business process architecture methods such as the BPTrends Business Process Architecture usually focus on developing a BPA in cases of existing business. On the other hand, the servitization context requires the creation of a new business. Therefore, answering the aforementioned research question, the traditional BPA approaches should be considerably adapted in three aspects when applied to PSS: the sequence

of activities, the steps and tools comprised in each activity of the method, and the inclusion of new activities specific for PSS context, such as assessing required changes on product's features. The aforementioned adaptations are substantial enough to generate a new method exclusive for servitization. Therefore, although the "roots" of the PSS BPA Development Method are connected to a traditional BPA method, the PSS BPA Development Method may be considered an innovation and not only an adaptation or instantiation.

Besides the aforementioned benefit, action research method facilitated that members of the company had more proximity with the customers and real experience in the servitization context. This enabled the generation of several insights that could be deeply analyzed and started promoting internal changes in the company, as explained in subsequent section 5.2. For example, the company's team testimonies show that action research contributed to the clarification of incorrect perceptions that the company had about its customers.

Furthermore, action research successfully contributed to the collaboration and exchange of knowledge between the company's team and the researchers. ImageCO Project Leader's testimony indicates that during the process, they "learned a lot" with the researchers, who "contributed with their experience and examples of other PSS practical cases that were fundamental for orienting decisions and proposing the solution". The other way around is also true. To cite one example, the researchers had the opportunity of learning from the experience of ImageCO with the unsuccessful intent in launching a PSS in the past. Besides that, the researchers also acquired practical knowledge during the proposition of the PSS BPA Development Method, what is only possible in empirical applications such as action research.

All these points are in agreement with the reasons previously described in section 2.2.3.2 for using action research in this study. Therefore, it is confirmed that action research fits the purpose of this study and has an appealing potential for being applied in future PSS researches.

Nevertheless, it is important to point out some cautions and improvement opportunities for future action research applications. First, due to the duality of the action research regarding the objectives of the company and the academy, there is a risk of the aims of the organizational project diverge from the scope of the research project. Especially in the case of this study, the company was requiring a much more advanced detailing

of processes than the Business Process Architecture's scope. This detailing is necessary for enabling the implementation and operation of the MOL and EOL phases of PSS; however, this is scope of future research projects of the Integrated Engineering Group (EI Group – research group in which the author of this study is a member). This "divergence" in aims is natural and happens frequently since the companies see a value in the researcher's contributions and want them to help as much as possible. Nevertheless, for the sake of guaranteeing the focus on the research's scope, it is important to clarify the scope of the action research with the company before it starts, and keep reminding it during the processes to avoid frustrations.

An improvement for the application of the action research in future studies consists of guaranteeing more than one researcher in all activities of the action research, as a means of assuring another perspective and contributing with the learning process by capturing more observations and enabling a discussion.

To conclude, although action research's outcomes cannot be generalized, the identification of some patterns in the specific applied case and previous experiences reported in literature may indicate a potential for generalization. The same context of servitization of ImageCO, which is characterized by the provision of a use-oriented PSS, with monthly fee (main income) and pay-per-use (for variable income when the permitted monthly amount of exams is reached) modalities, and based on an equipment that was previously sold, is also encountered in other cases of literature. To cite some, Whirlpool with the scheme of providing "purified water" per a monthly fee (BEUREN; FERREIRA; CAUCHICK, 2013, p. 226) and Interface with the provision of carpeting solutions for a monthly fee in the so called "Evergreen Lease" program (TISCHNER; VEZZOLI, 2009, p. 72). This may be a hint for testing the potential of generalization of the PSS BPA Development Method, and the business process reference model adapted from the Process Classification Framework (PCF) that was generated in this study.

5.2 Reflections about the servitization process

Besides contributing to the proposition of the PSS BPA Development Method, this research also arises interesting findings about the servitization processes and the organizational transformations involved in it:

- Although literature indicates that a separate organization for providing the PSS is the best solution in terms of facilitating the service-oriented cultural transformation (OLIVA; KALLENBERG, 2003, p. 166), in the practical field it may be difficult for companies to act like that, since that strategy requires higher investments and imposes higher operational costs. For example, during the Business Case ImageCO decided to change the initial strategy of opening a new subsidiary and considered launching the PSS within one of its current business units with the intent of promoting synergy and reducing initial investments and costs.
- Although the environmental benefits of PSS solutions are frequently indicated in literature (GOEDKOOP et al., 1999, p. 18; MANZINI; VEZZOLI, 2003, p. 852; VAN HALEN; VEZZOLI; WIMMER, 2005, p. 10), ImageCO neglected this aspect of sustainability. In the beginning of the action research, they were not interested in remanufacturing the equipment after the termination of a PSS contract. One testimony of an employee from ImageCO about this topic was “after five years the equipment becomes garbage”. It was only during the Business Case that ImageCO considered remanufacturing products, however, interested in the economic benefits. This episode shows the importance of defining and executing a rigid legislation for environmental issues.
- The company’s mindset and cultural transformation towards a service thinking shall start since the beginning of the servitization and reach all aspects, including the terminology. For example, the PSS services’ names should recollect a value to satisfy the customer’s need in respect to the solution or the service (“such as PSS activation”), instead of reminiscing a product-related action (“such as installation”). In the beginning of the action research, the terminology was product-oriented. That may have been caused because of the product-oriented mindset of the involved members of ImageCO and because some of the Design Thinking methods applied for defining the PSS Value Proposition are more appropriate for pure product development. The terminology was changed during the second action research cycle. The complete changes are described in section 4.3.2.

- Finally, by applying the action research approach with the main objective of proposing a method for the definition of the PSS BPA, the company already starts being transformed. Three signs of this transformation are:
    - The company's members started thinking and acting differently after the change in terminology, as described above. They gave the following testimonies: "It makes sense to change the terminology. It is not about scheduling an installation, but scheduling the activation of the service. We were still thinking about the solution as only a rental." In other situation, one member said, "have you perceived that I am using the PSS activation and not equipment installation terminology anymore?"
    - After identifying the necessity of new roles and positions for the PSS provision, the company already started training employees according to the new roles and organizing a recruitment process to hire new employees.
    - Required modifications in product component that were identified during the activity "Identify changes on product features" started to be implemented immediately.

Hence, besides the definition of the PSS BPA Development Method, which is the main objective of this research, the transformation of one specific manufacturing company into a PSS provider is also accomplished in this study.

5.3 Conclusion

The servitization process compels manufacturing companies aiming to become PSS providers to change their business processes by either creating new core processes to encompass customers' and stakeholders' requirements at a systematic level, or remodeling existing back-office processes to support the provision of new services and optimize profitability. Despite the existence of decades long successful PSS cases, such as the Power-by-the-hour program of Rolls Royce, operational difficulties are frequently reported in servitization cases. This fact was evidenced by the experience of ImageCO that had already tried to implement a PSS, but was unsuccessful. In order to overcome these obstacles during the servitization process, this study introduced the PSS BPA Development Method, which aims at supporting manufacturing companies in defining a business process architecture (BPA) for the operation of the middle of life

(MOL) and end of life (EOL) phases of their future PSS. Since not only a single process but also a collection of end-to-end business processes should be assessed and transformed during the PSS design and implementation in the context of servitization, the concept of business process architecture (BPA) is an appealing approach to start defining the business processes for the operation of a PSS.

The PSS BPA Development Method is part of a broader servitization process model called *PSS Transition Framework* (PIERONI et al., 2016). The PSS BPA Development Method was developed with the support of the Design Research Methodology (DRM), which comprises four research stages. In the first and second stages of DRM, a literature review on the main topics of the research (PSS and BPA) was conducted (chapter 3). A synthesis of this literature review (section 3.3) originated four theoretical requirements to guide the proposition of the PSS BPA Development Method.

During the third stage (chapter 4), action research approach was applied in order to empirically propose the PSS BPA Development Method. The action research was carried in a large multinational manufacturing company from the healthcare sector, which intended to transform a diagnostic imaging product offer into a PSS offer. After being improved in three action research cycles, the PSS BPA Development Method comprises twelve activities integrated in the *PSS Transition Framework*. These activities are performed with the support of different methods from BPM and servitization field.

At the end of the third stage, the research question (“How should existing methods from BPM field for defining BPA be applied during the servitization process to support manufacturing companies in defining their business processes for the operation (MOL and EOL phases) of a PSS?”) could be answered. It was identified that traditional BPA methods could be adapted in three aspects when applied to the PSS context:

(I) The sequence of activities;

(II) The steps and methods comprised in the activities, for example, servitization requires applying methods such as Design Thinking for developing a new value proposition instead of only diagnosing or understanding an existing value proposition of a business;

(III) The inclusion of specific activities for servitization context, such as identifying changes in product features for enabling the adaptation of the product architecture to the PSS context.

Finally, in the last stage the proposed method received a preliminary assessment with the intent of being prepared for further applications in case studies (section 4.6). All the predicted deliverables of the DRM methodology were successfully accomplished.

For practitioners, the contributions of this study are:

- The proposition of a BPA for operating the MOL and EOL phases of the future PSS;
- The support and knowledge that they obtained during the research; and,
- The transformational processes that already started to occur.

As for academy, the contributions comprise:

- The proposition of the PSS BPA Development Method;
- The application of action research method for obtaining more realistic solutions for the servitization and PSS field;
- The creation of a business process reference model's catalogue for supporting the development of BPAs;
- An analysis of potential business process reference models for the PSS context;
- The proposition of an adapted business process reference model for PSS based on the Process Classification Framework (PCF); and,
- The insights and findings obtained with the real case of servitization.

To conclude, the PSS BPA Development Method successfully accomplishes the main objective of this research, which was proposing a method, based on traditional BPA approaches, for operating the MOL and EOL phases of a PSS. Due to the empirical applied approach for proposing this method another accomplishment arises, which is the transformation of the company ImageCO towards a PSS provider.

5.4 Limitations and future research opportunities

Some limitations of this research should be considered in the interpretation of results.

First, the literature review comprehended non-scientific material related to business process reference models. This was necessary due to the nature of the Business Process Management area of knowledge, in which many business process reference models are developed by professional organizations, companies, consultancy firms, or normative institutions. Although they were not developed inside academic context, many academic authors from BPM field usually cite some of those models and recognize them as a good practice for supporting business process architecture definition.

Still on the topic of literature review, this study did not intend to be exhaustive and, therefore, information about process reference models, BPA methods, PSS typologies and methodologies may have been unexploited. Nevertheless, the author tried to reduce this risk by exploring previous bibliometric studies on the aforementioned topics whenever it was possible (such as in sections 3.1.3.6, 3.1.6, 3.2.4, and 3.2.5).

Concerning the results, the main limitation is that the PSS BPA Development Method and the adapted Process Classification Framework reference model for PSS context were proposed based on empirical application in one single company. This refrains the researcher from doing any kind of generalization due to the occurrence of potential biases and peculiarities associated with the specific organizational environment. Therefore, an opportunity for future researches is to apply the proposed PSS BPA Development Method in case studies involving organizations of multiple sectors with the same PSS characteristics of ImageCO (provision of a use-oriented PSS, with monthly fee and pay-per-use modalities, and based on an equipment that were previously sold) and also in different types of PSS offers, such as result-oriented cases.

Regarding the business process reference model (PCF) adapted for proposing the PSS BPA, there is an opportunity for further investigating in practice the adherence of other reference models to PSS context. For example, the CMMI-Services (CMMI-SVC) presented a score almost as high as the PCF for the aspect “PSS Capabilities” and even scored higher than PCF in some criteria (such as partnership, PSS design and delivery, and process management), as described in section 4.2.2.1.3. Future research could explore how to combine the different CMMI models for Services (which focus on the customer service chain), for Acquisition (which contains strong orientation to partnership management), and for Development (which is strong in product

development) in order to obtain a more complete adapted reference model in terms of PSS capabilities.

Another limitation is that this study approaches structuring or changing a BPA with a major focus on innovations driven by business processes transformations. Nevertheless, it is important to highlight that focusing only on the business process side of BPA increase the risk of overlooking IT-driven or IoT-driven innovations on BPA.

In addition, different circumstances may be the trigger for the PSS design initiative inside a company. This study focuses only on the situation when the company actively decides to offer the PSS after perceiving a market opportunity. Another trigger to start a PSS would be a direct request from a customer. In this case, the customer may suggest an initial concept of the PSS value proposition, which may change the way in which the *PSS Transition Framework* was applied, affecting the PSS BPA Development Method was applied. Since evidences to test this last situation were not obtained in the action research, the topic remains as an opportunity for future researches.

Although the aspects of sustainability and circular economy are frequently associated to PSS in literature, they were narrowly explored in this study due to the disinterest of the company that participated in the action research in such topics. These aspects are very important and could be explored in further applications of the PSS BPA Development Method. One possible idea for future research is applying different methods and tools oriented to sustainability for developing the value proposition of the PSS. One example could be the Sustainable Value Analysis tool developed by Yang et al. (2014).

As previously presented in section 5.1 another research opportunity consists of improving the PSS BPA Development Method by connecting the Business Case definitions with the detailed process model in a more smooth way. Moreover, the use of different Design Thinking methods more oriented to services development or even specific for PSS development could be applied during the PSS Value Proposition definition for improving the PSS offer terminology.

Finally, future research shall investigate how the PSS BPA developed during the BOL, may be refreshed with inputs from subsequent methods being applied for obtaining the

remaining deliverables of the *PSS Transition Framework* (Detailing, Value Chain Preparation, and Value Chain Launch), and especially with inputs from the operation phase (MOL and EOL phases).

6 References

ABRAMOVICI, M. et al. Systematization of IPS2 Diversification Potentials Using Product Lifecycle Data. **Procedia CIRP**, v. 47, p. 288–293, 2016.

ADRODEGARI, F.; SACCANI, N.; KOWALKOWSKI, C. A Framework for PSS Business Models: Formalization and Application. **Procedia CIRP**, v. 47, p. 519–524, 2016.

AITKEN, C.; STEPHENSON, C.; BRINKWORTH, R. Process Classification Frameworks. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on business Process Management, vol. 2.** 1st. ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010. p. 71–90.

ALONSO-RASGADO, T.; THOMPSON, G. A rapid design process for Total Care Product creation. **Journal of Engineering Design**, v. 17, n. 6, p. 509–531, 2006.

AMIGO, C. **Modelos de referência para o processo de desenvolvimento de produtos: novas possibilidade de representação**. [s.l.] Escola de Engenharia de São Carlos, Universidade de São Paulo, 2013.

ANDERSEN, J. B. et al. **PSS Partnerships: A workbook in the PROTEUS series, PRO-06,**. Denmark: Technical University of Denmark, 2013a.

ANDERSEN, J. B. et al. **PSS Business Models: A workbook in the PROTEUS series, PRO-07,**. Denmark: Technical University of Denmark, 2013b.

APQC. **Cross Industry Process Classification Framework, Version 7.0.2**. Disponível em: <<https://www.apqc.org/pcf>>. Acesso em: 30 nov. 2015.

AREDES, E. L. **Método de elaboração de Arquitetura de Processos para a promoção de Gestão por Processos em instituições de ensino superior públicas**. [s.l.] Faculdade de Economia, Admnistração e Contabilidade de Ribeirão Preto, Universidade de São Paulo, 2013.

AREDES, E. L.; PÁDUA, S. I. D. DE. Process Architecture as a BPM Critical Success Factor: A Bibliographic Review. **Business and Management Review**, v. V4, n. Special Issue, p. 245–255, 2014.

ARMISTEAD, C.; PRITCHARD, J.-P.; MACHIN, S. Strategic Business Process Management for Organisational Effectiveness. **Long Range Planning**, v. 32, n. 1, p. 96–106, 1999.

AURICH, J. C.; FUCHS, C.; WAGENKNECHT, C. Life cycle oriented design of technical Product-Service Systems. **Journal of Cleaner Production**, v. 14, p. 1480–1494, 2006.

BAGHERI, S.; KUSTERS, R. J.; TRIENEKENS, J. Business-IT Alignment in PSS Value Networks: A Capability-Based Framework. In: L.M. CAMARINHA-MATOS AND H. AFSARMANESH (EDS.): (Ed.). . **Collaborative Systems for Smart Networked Environments: 15th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2014, Amsterdam, The Netherlands, October 6-8, 2014. Proceedings**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014. p. 273–284.

BAINES, T. S. et al. State-of-the-art in product service-systems. **Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture**, v. 221, n. 10, p. 1543–1552, 2007.

BAINES, T. S. et al. The servitization of manufacturing. **Journal of Manufacturing Technology Management**, v. 20, n. 5, p. 547–567, 2009a.

BAINES, T. S. et al. Towards an operations strategy for product-centric servitization. **International Journal of Operations and Production Management**, v. 29, n. 5, p. 494–519, 2009b.

BARQUET, A. P. B. et al. Employing the business model concept to support the adoption of product-service systems (PSS). **Industrial Marketing Management**, v. 42, n. 5, p. 693–704, 2013.

BARQUET, A. P. B. **Creation of product-service systems (PSS) proposals in the fuzzy front-end.** Doctoral dissertation—[s.l.] University of São Paulo, 2015.

BARROS, O.; JULIO, C. Enterprise and process architecture patterns. **Business Process Management Journal**, v. 17, n. 4, p. 598–618, 2011.

BASKERVILLE, R. L. Investigating information systems with action research. **Communications of the Association for Information Systems**, v. 2, n. 19, p. 32, 1999.

BASKERVILLE, R.; MYERS, M. D. Special Issue on Action Research in Information Systems - Making IS Research Relevant To Practice - Foreword. **MIS Quarterly**, v. 28, n. 3, p. 329–335, 2004.

BECKER, J.; BEVERUNGEN, D. F.; KNACKSTEDT, R. The challenge of conceptual modeling for product-service systems: Status-quo and perspectives for reference models and modeling languages. **Information Systems and e-Business Management**, v. 8, n. 1, p. 33–66, 2010.

BECKER, J.; BEVERUNGEN, D.; KNACKSTEDT, R. **Reference Models and Modeling Languages for Product-Service Systems – Status-Quo and Perspectives for Further Research.**41st Hawaii International Conference on System Sciences. **Anais**...2008

BECKER, J.; KUGELER, M.; ROSEMANN, M. **Process Management**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2003.

BEUREN, F. H.; FERREIRA, M. G.; CAUCHICK, P. A. Product-service systems: A literature review on integrated products and services. **Journal of Cleaner Production**, v. 47, p. 222–231, 2013.

BLESSING, L. T. M.; CHAKRABARTI, A. **DRM: A Design Research Methodology**. London: Springer, 2009.

BOEHM, M.; THOMAS, O. Looking beyond the rim of one's teacup: A multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. **Journal of Cleaner Production**, v. 51, p. 245–260, 2013.

BOUCHER, X.; PEILLON, S. **Diagnosis of Servitisation Potential Proposal of a Strategic Diagnosis Framework dedicated to SME.**WECC2015, World Engineering Conference and Convention 2015, Track Industry for Society,. **Anais**...2015

BREZET, J. C. et al. The Design of Eco-Efficient Services. **Delft University of Technology, Design for Sustainability Program, Delft,** p. 599–616, 2001.

BUCKL, C. et al. The software car: Building ICT architectures for future electric

vehicles. **2012 IEEE International Electric Vehicle Conference, IEVC 2012**, 2012.

BURLTON, R. Delivering business strategy through process management. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on business Process Management, vol. 2.** 1st. ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010. p. 5–36.

BURLTON, R. Delivering Business Strategy Through Process Management. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on Business Process Management 2, 2nd Edition**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. p. 45–78.

CAVALIERI, S.; PEZZOTTA, G. Product – Service Systems Engineering : State of the art and research challenges. **Computers in Industry**, v. 63, n. 4, p. 278–288, 2012.

CBOK, B. **Guide to the Business Process Management Common Body of Knowledge. Version 3.0.** Disponível em: <<http://c.ymcdn.com/sites/www.abpmp.org/resource/resmgr/Docs/ABPMP_CBOK_Guide_English.pdf>>. Acesso em: 1 jul. 2016.

CESCHIN, F. Critical factors for implementing and diffusing sustainable product-Service systems: Insights from innovation studies and companies' experiences. **Journal of Cleaner Production**, v. 45, p. 74–88, 2013.

CLAYTON, R. J.; BACKHOUSE, C. J.; DANI, S. Evaluating existing approaches to product-service system design: A comparison with industrial practice. **Journal of Manufacturing Technology Management**, v. 23, n. 3, p. 272–298, 2012.

COOPER, R. G. Predevelopment activities determine new product success. **Industrial Marketing Management**, v. 17, n. 3, p. 237–247, ago. 1988.

COOPER, R.; SLAGMULDER, R. Interorganizational cost management and relational context. **Accounting, Organizations and Society**, v. 29, n. 1, p. 1–26, 2004.

COUGHLAN, P.; COGHLAN, D. Action research for operations management. **International Journal of Operations and Production Management**, v. 22, n. 2, p. 220–240, 2002.

COUGHLAN, P.; COGHLAN, D. Action Research. **Researching Operations Management**, 2009.

CURIAZZI, R. et al. Process Standardization to Support Service Process Assessment and Re-engineering. **Procedia CIRP**, v. 47, p. 347–352, 2016.

DAHMANI, S.; BOUCHER, X.; PEILLON, S. **Industrial transition through Product-Service Systems: Proposal of a decision-process modeling framework.**Working Conference on Virtual Enterprises. **Anais**...Spinger Berlin Heidelberg, 2013

DIJKMAN, R.; VANDERFEESTEN, I.; REIJERS, H. A. The Road to a Business Process Architecture: An Overview of Approaches and their Use. **Beta Working Paper series 350**, v. 350, n. July, p. 1–17, 2011.

DUMAS, M. et al. **Fundamentals of Business Process Management**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013.

DURUGBO, C. Managing partnership uncertainty for sustainable services: A conceptual model. **IFIP Advances in Information and Communication**

Technology, v. 408, p. 355–362, 2013.

EDER, S. et al. Estudo das práticas de gerenciamento de projetos voltadas para desenvolvimento de produtos inovadores. **Produto & Produção**, v. 13, n. 1, p. 148–165, 2012.

EID-SABBAGH, R.-H.; WESKE, M. Analyzing Business Process Architectures. In: **Advanced Information Systems Engineering**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013. p. 208–223.

EXNER, K. et al. Validation of Product-Service Systems - A prototyping approach. **Procedia CIRP**, v. 16, p. 68–73, 2014.

FALAGAS, M. E. et al. Comparison of PubMed , Scopus , Web of Science , and Google Scholar : strengths and weaknesses. **The Faseb Journal**, v. 22, n. 2, p. 338–342, 2008.

FETTKE, P.; LOOS, P. Classification of reference models: a methodology and its application. **Information Systems and e-Business Management**, v. 1, n. 1, p. 35–53, 2003.

FETTKE, P.; LOOS, P. Using Reference Models for Business Engineering - State-of-the-Art and Future Developments. **Innovations in Information Technology, 2006**, p. 1–5, 2006.

FETTKE, P.; LOOS, P.; ZWICKER, J. **Business Process Reference Models: Survey and Classification.**International Conference on Business Process Management. **Anais**...2005

GARCIA, R.; CALANTONE, R. A critical look at technological innovation typology and innovativeness terminology: A literature review. **Journal of Product Innovation Management**, v. 19, n. 2, p. 110–132, 2002.

GEBAUER, H.; BRAVO-SANCHEZ, C.; FLEISCH, E. Service strategies in product manufacturing companies. **Business Strategy Series**, v. 9, n. 1, p. 12–20, 2007.

GENGNAGEL, C.; NAGY, E.; STARK, R. **Rethink! Prototyping**. Cham: Springer International Publishing, 2016.

GEROSA, M.; TAISCH, M. **Industrial services reference model**1st CIRP Industrial Product-Service System (IPS2) Conference. **Anais**...2009

GILL, J.; JOHNSON, P. **Research Methods for Managers**. London: Sage Publications Ltd, 2002.

GOEDKOOP, M. et al. **Product-Service Systems, Ecological and Economic Basics.**Report for Dutch Ministries of environment (VROM) and economic affairs (EZ), , 1999.

HARMON, P. The Scope and Evolution of Business Process Management. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on business Process Management, vol. 1.** 2nd. ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. p. 37–80.

HEDEGAARD, S.; SIMONSEN, J. G. Extracting usability and user experience information from online user reviews. **SIGCHI Conference on Human Factors in Computing Systems - CHI '13**, p. 2089, 2013.

HELLEK, K. et al. **PSS Tool Book: A workbook in the PROTEUS series, PRO-04,**.

Denmark: Technical University of Denmark (DTU)., 2013.

HORD, S. M. **Working Together: Cooperation or Collaboration?** Austin: Texas University, 1981.

HOUY, C.; FETTKE, P.; LOOS, P. Empirical research in business process management – analysis of an emerging field of research. **Business Process Management Journal**, v. 16, n. 4, p. 619–661, 2010.

HOUY, C.; FETTKE, P.; LOOS, P. Business Process Frameworks. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on Business Process Management 2, 2nd Edition**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. p. 153–175.

ISACA. **COBIT Framework**. Disponível em: <https://cobitonline.isaca.org/>. Acesso em: 10 fev. 2016.

IT PROCESS MAPS GBR. **Introduction: ITIL Version 3 and the ITIL Process Map V3**. Disponível em: <http://ftp.psu.ac.th/pub/itil/introduction_itil_process_map_v3.pdf>. Acesso em: 10 fev. 2016.

IVANOV, K.; REUL, D. E. A. **Systems and methods for modeling business processes**Google Patents, , 2007. Disponível em: <https://www.google.com/patents/US20070005618>

JOHNE, A.; STOREY, C. New service development: a review of the literature and annotated bibliography. **European Journal of Marketing**, v. 32, n. 3/4, p. 184–251, 1998.

KEELEY, L. et al. **Ten types of innovation: The discipline of building breakthroughs.** [s.l.] John Wiley & Sons, 2013.

KIMITA, K.; SHIMOMURA, Y. Development of the design guideline for product-service systems. **Procedia CIRP**, v. 16, p. 344–349, 2014.

KORHERR, B.; LIST, B. Extending the EPC and the BPMN with business process goals and performance measures. **ICEIS 07 - 9th International Conference on Enterprise Information Systems**, p. 287–294, 2007.

KOWALKOWSKI, C. et al. What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies. **Industrial Marketing Management**, v. 45, p. 59–69, 2015.

KRUCKEN, L.; MERONI, A. Building stakeholder networks to develop and deliver product-service-systems: practical experiences on elaborating pro-active materials for communication. **Journal of Cleaner Production**, v. 14, n. 17, p. 1502–1508, 2006.

LEVIN, M. Action research and the research community. **Concepts and Transformation**, v. 8, n. 3, p. 275–280, 2003.

LINDAHL, M.; RÖNNBÄCK, A. Ö.; SAKAO, T. **Business Implications of Integrated Product and Service Offerings**Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference. **Anais**...2009

LIST, B.; KORHERR, B. An Evaluation of Conceptual Business Process Modelling Languages. **2006 ACM symposium on Applied computing**, n. Section 3, p. 1532–1539, 2006.

MACEDO DE MORAIS, R. et al. An analysis of BPM lifecycles: from a literature review to a framework proposal. **Business Process Management Journal**, v. 20, n. 3, p. 412–432, 27 maio 2014.

MADDERN, H. et al. End-to-end process management: implications for theory and practice. **Production Planning and Control**, v. 25, n. 16, p. 1303–1321, 2013.

MALINOVA, M.; LEOPOLD, H.; MENDLING, J. An Explorative Study for Process Map Design. In: NURCAN, S.; PIMENIDIS, E. (Eds.). . **Information Systems Engineering in Complex Environments**. Lecture Notes in Business Information Processing. Cham: Springer International Publishing, 2015. v. 204p. 36–51.

MANZINI, E.; VEZZOLI, C. A strategic design approach to develop sustainable product service systems: Examples taken from the “environmentally friendly innovation” Italian prize. **Journal of Cleaner Production**, v. 11, n. 8 SPEC., p. 851–857, 2003.

MARTINEZ, V. et al. Challenges in transforming manufacturing organisations into product-service providers. **Journal of Manufacturing Technology Management**, v. 21, n. 4, p. 449–469, 2010.

MEIER, H. et al. Key performance indicators for assessing the planning and delivery of industrial services. **Procedia CIRP**, v. 11, p. 99–104, 2013.

MEIER, H.; KRUG, C. M. **Standardization of Service Delivery in Industrial Product-Service Systems**1st CIRP Industrial Product-Service System (IPS2) Conference. **Anais**...2009

MEIER, H.; ROY, R.; SELIGER, G. Industrial Product-Service Systems—IPS2. **CIRP Annals - Manufacturing Technology**, v. 59, n. 2, p. 607–627, jan. 2010.

METTERS, R.; VARGAS, V. Typology of de-coupling strategies in mixed services. **Journal of Operations Management**, v. 18, n. 6, p. 663–682, 2000.

MONT, O.; DALHAMMAR, C.; JACOBSSON, N. A new business model for baby prams based on leasing and product remanufacturing. **Journal of Cleaner Production**, v. 14, n. 17, p. 1509–1518, 2006.

MONT, O. K. Clarifying the concept of product – service system. **Journal of Cleaner Production**, v. 10, p. 237–245, 2002.

MONT, O. K. **Product–service system: Panacea or myth?** Thesis—[s.l.] Lund University, 2004.

MORELLI, N. Developing new product service systems (PSS): methodologies and operational tools. **Journal of Cleaner Production**, v. 14, n. 17, p. 1495–1501, 2006.

MÜLLER, P.; STARK, R. **A Generic PSS Development Process Model Based on Theory and an Empirical Study**11th International Design Conference DESIGN. **Anais**...2010

NAPPI, V. **Framework para Desenvolver um Sistema de Medição de Desempenho para PLM (Product Lifecycle Management) com Indicadores de Sustentabilidade**. [s.l.] Escola de Engenharia de São Carlos, Universidade de São Paulo, 2014.

NEELY, A. et al. Performance measurement system design: developing and testing a process-based approach. **International Journal of Operations & Production Management**, v. 20, n. 10, p. 1119–1145, 2000.

NEELY, A. Exploring the financial consequences of the servitization of manufacturing. **Operations Management Research**, v. 1, p. 103–118, 2009.

NEU, W. A.; BROWN, S. W. Forming Successful Business-to-Business Services in Goods-Dominant Firms. **Journal of Service Research**, v. 8, n. 3, p. 3–17, 2005.

OLIVA, R.; KALLENBERG, R. Managing the transition from products to services. **International Journal of Service Industry Management**, v. 14, n. 2, p. 160–172, 2003.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). **Oslo Manual: Guidelines for collecting and interpreting innovation data**. Disponível em: <http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Oslo+Manual#0>. Acesso em: 26 fev. 2016.

OSADSKY, P. et al. Improving service operation performance by a cross-industry reference model. **IFIP International Federation for Information Processing**, v. 246, p. 397–404, 2007.

OSTERWALDER, A.; PIGNEUR, Y. **Business Model Generation**. Amsterdam: Self Published, 2010.

OULD, M. Designing a re-engineering proof process architecture. **Business Process Management Journal**, v. 3, n. 3, p. 232–247, 1997.

PARK, Y.; GEUM, Y.; LEE, H. Toward integration of products and services: Taxonomy and typology. **Journal of Engineering and Technology Management - JET-M**, v. 29, n. 4, p. 528–545, 2012.

PEZZOTTA, G.; CAVALIERI, S.; GAIARDELLI, P. A spiral process model to engineer a product service system: An explorative analysis through case studies. **CIRP Journal of Manufacturing Science and Technology**, v. 5, n. 3, p. 214–225, 2012.

PIERONI, M. et al. Transforming a Traditional Product Offer into PSS: A Practical Application. **Procedia CIRP**, v. 47, p. 412–417, 2016.

PLATTNER, H. **Bootcamp Bootleg**. Palo Auto: Design School Stanford, 2010.

PMI. **PMBoK - Guide to the project Management body of knowledge**, 2013.

POLENSKE, K. Competition, Collaboration and Cooperation: An Uneasy Triangle in Networks of Firms and Regions. **Regional Studies**, v. 38, n. 9, p. 1029–1043, 2004.

PUHAKAINEN, P.; SIPONEN, M. Improving Employees' Compliance Through Information Systems Security Training: An Action Research Study. **MIS Quarterly**, v. 34, n. 4, p. 757–778, 2010.

QU, M. et al. State-of-the-art of design, evaluation, and operation methodologies in product service systems. **Computers in Industry**, v. 77, n. 127, p. 1–14, 2016.

REIJERS, H. A.; MENDLING, J.; RECKER, J. Business Process Quality Management. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on business Process Management, vol. 1.** Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. p. 167–185.

REINARTZ, W.; ULAGA, W. How to Sell Services More Profitably. **Harvard Business Review**, v. 86, n. 5, p. 90, 2007.

RODRIGUES, K. F. D. C.; NAPPI, V.; ROZENFELD, H. A Proposal to Support the

Value Proposition in Product Oriented Service Business Model of Product Service Systems. **Procedia CIRP**, v. 16, p. 211–216, 2014.

ROSA, M. et al. **Application of design thinking towards a PSS concept definition : A case study**International Conference on Transdisciplinary Engineering. **Anais**...2016

ROSEMANN, M. Application reference models and building blocks for management and control. In: BEMUS, P.; NEMES, L.; SCHMIDT, G. J. (Eds.). . **Handbook on Enterprise Architecture**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2003. p. 595–615.

ROY, R. Sustainable product-service systems. **Futures**, v. 32, n. 3–4, p. 289–299, abr. 2000.

RUMMLER, G. A; RAMIAS, A. J. A framework for defining and designing the structure of work. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on Business Process Management 1**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010. p. 83–106.

RUMMLER, G. A; RAMIAS, A. J. A framework for defining and designing the structure of work. In: VOM BROCKE, J.; ROSEMANN, M. (Eds.). . **Handbook on Business Process Management 1, 2nd Edition**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015. p. 81–104.

SABBAGH, R.-H.; DIJKMAN, R.; WESKE, M. Business Process Architecture: Use and Correctness. **Business Process Management, 10th International Conference, BPM 2012, Tallinn, Estonia, September 3-6, 2012. Proceedings**, p. 65–81, 2012.

SCHEER, A.; JOST, W.; GUNGOZ, Ö. A Reference Model for Industrial Enterprises. In: **Reference Modeling for Business Systems Analysis**. [s.l.] IGI Global, 2007. p. 167–181.

SHAFER, S. M.; SMITH, H. J.; LINDER, J. C. The power of business models. **Business Horizons**, v. 48, n. 3, p. 199–207, 2005.

SILVESTRO, R. et al. Towards a Classification of Service Processes. **International Journal of Service Industry Management**, v. 3, n. 3, p. 2–75, 1992.

SMITH, D. J. Power-by-the-hour: the role of technology in reshaping business strategy at Rolls-Royce. **Technology Analysis & Strategic Management**, v. 25, n. 8, p. 987–1007, set. 2013.

SUPPLY CHAIN COUNCIL. **SCOR: Supply Chain Operations Reference Model Version 10.0.**, 2010a.

SUPPLY CHAIN COUNCIL. Customer-Chain Operations Reference-Model (CCOR) Version 1.0. p. 3, 2010b.

TAN, A. R. et al. **Strategies for Designing and Developing Services for Manufacturing Firms**Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference. **Anais**...2009

TAN, A. R. **Service-oriented product development strategies**. PhD thesis—[s.l.] Technical University of Denmark (DTU), 2010.

TAN, A. R.; MCALOONE, T. C. Characteristics of strategies in product/service-system development. **9th International Design Conference, DESIGN 2006**, p.

1435–1442, 2006.

TATIKONDA, M. V; ZEITHAML, V. A. Managing the new service development process: multi-disciplinary literature synthesis and directions for future research. **New directions in supply-chain management**, p. 200–33, 2002.

TAYLOR III, L. J.; MURPHY, B.; PRICE, W. Goldratt's thinking process applied to employee retention. **Business Process Management Journal**, v. 12, n. 5, p. 646–670, 2006.

TEAM, C. P. **CMMI for Acquisition, Version 1.3**. Disponível em: <http://www.sei.cmu.edu/reports/10tr032.pdf>. Acesso em: 15 out. 2016a.

TEAM, C. P. **CMMI for Development, Version 1.3**. Disponível em: <www.sei.cmu.edu/reports/10tr033.pdf, CMU/SEI-2010-TR-033>. Acesso em: 15 out. 2016b.

TEAM, C. P. **CMMI for Services, Version 1.3**. Disponível em: <papers3://publication/uuid/0BBB913C-B8C4-425E-8899-661946CB056D>. Acesso em: 25 out. 2016c.

TEECE, D. J. Business models, business strategy and innovation. **Long Range Planning**, v. 43, n. 2–3, p. 172–194, 2010.

TISCHNER, U.; VEZZOLI, C. Module C: Product-Service Systems; Tools and Cases. **Design for Sustainability (D4S): A Step-By-Step Approach**, p. 33–75, 2009.

TM FORUM. **Business Process Framework (eTOM) Release 9**. Disponível em: <https://www.tmforum.org/business-process-framework/>. Acesso em: 10 fev. 2016.

TRAN, T.; PARK, J. Y. Development of a Strategic Prototyping Framework for Product Service Systems Using Co-creation Approach. **Procedia CIRP**, v. 30, p. 1–6, 2015.

TUKKER, A. Eight types of product-service system: Eight ways for sustainability? Experiences from SUSPRONET. **Business Strategy and the Environment**, n. 13, p. 246–260, 2004.

TUKKER, A. Product services for a resource-ef fi cient and circular economy - a review. **Journal of Cleaner Production**, v. 97, p. 76–91, 2015.

TUKKER, A.; TISCHNER, U. Product-services as a research field: past, present and future. Reflections from a decade of research. **Journal of Cleaner Production**, v. 14, n. 17, p. 1552–1556, 2006.

ULAGA, W.; KONDIS, A.; MCTEAGUE, L. From Product to Service: Navigating the Transition. **Insights@IMD**, n. 26, p. 1–4, 2013.

ULAGA, W.; REINARTZ, W. J. Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully. **Journal of Marketing**, v. 75, n. 6, p. 5–23, 2011.

ULRICH, K. T.; EPPINGER, S. D. **Product design and development**, 2012.

VALUE CHAIN GROUP. **Value Reference Model (VRM), Version 3 Rev 1**. Disponível em: <http://www.value-chain.org/vrm>. Acesso em: 10 out. 2016.

VAN HALEN, C.; VEZZOLI, C.; WIMMER, R. **Methodology for Product Service System Innovation**. 1st ed ed. The Hague: Koninklijke Van Gorcum, 2005.

VANDERMERWE, S.; RADA, J. Servitization of business: Adding value by adding

services. **European Management Journal**, v. 6, n. 4, p. 314–324, 1988.

VASANTHA, G. V. A. et al. A review of product–service systems design methodologies. **Journal of Engineering Design**, v. 23, n. 9, p. 635–659, 2012.

VOM BROCKE, J.; ROSEMANN, M. **Handbook on Business Process Management 1**. Berlin, Heidelberg: Spinger Berlin Heidelberg, 2015.

WELP, E. G. et al. **Modelling Approach for the Integrated Development of Industrial Product-Service Systems.**The 41st CIRP Conference on Manufacturing Systems. **Anais**...2008

WILBERG, J.; HOLLAUER, C.; OMER, M. Supporting the performance assessment of Product-Service Systems during the use phase. **Procedia CIRP**, v. 30, p. 203–208, 2015.

WIRTZ, B. W. et al. Business Models: Origin, Development and Future Research Perspectives. **Long Range Planning**, p. 1–19, 2015.

WRASSE, K.; HAYKA, H.; STARK, R. Development and Evaluation of Solar Energy B2B Solutions. **Procedia CIRP**, v. 47, p. 364–369, 2016.

XING, K.; NESS, D. Transition to Product-service Systems: Principles and Business Model. **Procedia CIRP**, v. 47, p. 525–530, 2016.

YANG, M. et al. Sustainable Value Analysis Tool for Value Creation. **Asian Journal of Management Science and Application**, v. 1, n. 4, p. 312–332, 2014.

YANG, M.; RANA, P.; EVANS, S. Product service system (PSS) life cycle value analysis for sustainability. **The 6th International Conference on Design and Manufacture for Sustainable Development (ICDMSD)**, n. January 2013, 2013.

YIN, R. K. **Qualitative Research from Start to Finish**, 2011.

ZANCUL, E. DE S. et al. Business process support for IoT based product-service systems (PSS). **Business Process Management Journal**, v. 22, n. 2, p. 305–323, 4 abr. 2016.

Appendix A – Semi-structured questionnaire for activity *Define Context and Purpose (A.3.1)*

This appendix comprises the semi-structured questionnaire that supported the researcher with a mental framework for conducting the interviews of the task “Define Context and Purpose”. It comprises main topics that the researcher approached during the interview as follows:

- Strategy with current product
  - What have the company been doing for expanding its participation in diagnostic imaging market?
  - What is the market share of the current diagnostic imaging product?
  - Is there opportunity for expanding? How much?
  - How representative is the current product in terms of income for the company?
  - What are the synergies with other products from the portfolio?
  - The transactions are mainly B2B, B2C, or B2G?
  - How many equipment are currently installed?
  - What is the geographical distribution?
  - What are the variations of the current products?
  - What are the segments that current products reach?
  - Are there selling patterns in different geographical regions?
- Expectations about PSS offer
  - What does the company expect with the PSS offer?
- Market forces
  - Current and potential competitors
  - Current and potential customer segments
  - Substitute products or services
- Suppliers and value chain partners
  - Who are the suppliers and partners?
  - What is the level of dependence?
  - Are there potential new suppliers and partners?
- Stakeholders
  - Besides clients and suppliers, who else may influence the PSS design and the current Market?
  - Does employees influence it? Government?
- Technological trends
  - Are there opportunities or threats regarding technological aspects?
- Regulatory trends
  - Are there regulatory issues affecting the sector? Which ones?
- Social and cultural trends

    - Are there cultural or social trends impacting current product?
    - Are there opportunities for the future?
- Macro-economic trends
    - How is this sector in other countries?
    - Are there similarities or opportunities?
    - How are financing opportunities in the country?
    - Is it viable to obtain credit in banks, governments?
    - Is there availability of resources for current market?

Appendix B – Semi-structured questionnaires for activity *Diagnose (A.3.2)*

This appendix comprises the semi-structured questionnaires that supported the conduction of interviews in the activity “Diagnose”.

In each interview of this activity, the questionnaire presented in Appendix A was applied and complemented by specific questions that varied according to the respondents’ role as described below:

Salesperson

- Is the current product well positioned in comparison with the competitors’ products?
- Do you sell other types of product?
- How many diagnostic imagining products do you sell monthly?
- Can you describe the activities involved in the process of selling until delivering products to customers?
- How do you participate in it?
- Describe your role’s attributions
- What are your interfaces with other functional areas?
- What are customer needs?
- How do you measure success in sales?
- Have you participated in the last attempt to implement a PSS offer with the same product?

Technical assistance coordinator

- What are the recurrent technical problems in the current product?
- What are their technical complexity?
- How long does it take to fix them (mean)?
- Can you describe the activities involved in the process of receiving incidents until they are concluded?
- Are there suppliers involved in any activity?

- Are there key performance indicators for monitoring maintenance service level?
- Is service level provision and requirements similar to all geographical regions?
- What are customers' need regarding technical assistance?
- Are customers satisfied?
- How do competitors perform regarding technical assistance?

Tax and legal coordinator

- Regarding regulatory and tax laws, what are the differences between selling physical product and selling services?
- Are there law suits involving current diagnostic imaging product?
- Did you participate in the last attempt to implement a PSS offer with the diagnostic imaging product? Can you describe how it was performed and what were the main causes of failure in your opinion?
- Are there legal restrictions for involving external partners in the PSS offer?
- From a legal perspective, describe how is the interaction of the company with banks (for financing), regulatory agencies, industry organizations, customers, end-users. Are there any legal restrictions or issues?

Customer

- What are the necessities that you have regarding the current diagnostic imaging product?
- What types of service are associated with the product?
- Are you satisfied with current product? Why or why not?
- How are competitors when compared to ImageCO?

Appendix C –Business Process Reference Model Catalogue

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continues)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Supply Chain Operations Reference Model (SCOR)	3	Detailed	Manufacturing	Supply Chain Management	Defining a general architecture (including business processes, performance metrics, and best practices) for operating supply chain processes.	SCOR defines the Supply Chain architecture for high-level processes, leaving the implementation level (4th level) to each company. SCOR does not envision business processes under marketing and sales, research and development, and management and supporting processes for the business. Therefore, SCC has designed new models, such as DCOR, CCOR, and PLCOR to complement SCOR. For lowest level processes, it contains metrics to measure performance and links between processes.	Industry Consortium	Supply Chain Council (SCC) (2010)	18	Restricted
IT Infrastructure Library (ITIL)	3	Detailed	Services	Information Technology Management	Defining best practices (including business processes, concepts and principles, roles and responsibilities and performance metrics) for the provision and management of IT services, which may occur in either an IT department or IT enterprise.	ITIL describes key processes, key concepts and principles, key roles and responsibilities and according KPI's in five different areas of IT service management: service strategy, service design, service transition, service operation and continual service improvement.	Government	Office of Government Commerce (OGC), UK (1989); IT Process Maps GbR (2009)	13	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Capability Maturity Model Integration for Development (CMMI-DEV V 1.3)	3	Detailed	Generic	Systems and Software Engineering	Providing best practices and guidelines from government and industries for improving the development process of products and services.	CMMI collection of models is required by many United States Government contracts, especially in software development. Any CMMI model contains a set of common Generic Goals and Generic Practices. In addition, each individual model (services, development, and acquisition) comprises a set of different Process Areas, which describe each model's expected components, related informative components, including subpractices, notes, examples, and example work products.	Academy	Carnegie Mellon® Software Engineering Institute (SEI) (2010); Team (2010)	9	Public
Capability Maturity Model Integration for Services (CMMI-SVC V1.3)	3	Detailed	Generic	Systems and Software Engineering	Providing best practices and guidelines from government and industries for activities related to service provision to customers and end-users.	Likewise CMMI-DEV V1.3.	Academy	Carnegie Mellon® Software Engineering Institute (SEI) (2010); Team (2010)	9	Public

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Capability Maturity Model Integration for Acquisition (CMMI-ACQ V1.3)	3	Detailed	Generic	Systems and Software Engineering	Providing best practices and guidelines from government and industries for processes related to acquiring product and services to meet the needs of customers and end-users. Although acquisition activities involve the perspective of the supplier, this model's focus is on the acquirer processes.	Likewise CMMI-DEV V1.3.	Academy	Carnegie Mellon® Software Engineering Institute (SEI) (2010); Team (2010)	9	Public
Process Classification Framework (PCF)	3	Detailed	Generic	Neutral	Facilitating process management and improvement. Provide a general architecture (including business processes, performance metrics and best practices) for all business processes of an enterprise, such as operating (core or primary), management and supporting services processes.	It describes processes in a 5-level hierarchy ("Category", Process Group, Process, Activity, and Tasks). From the generic cross-industry view, APQC developed specific frameworks for 19 sectors.	Industry Consortium	The American Productivity and Quality Center (APQC) (2015)	5	Public
Enhanced Telecom Operations Map (eTOM)	3	Detailed	Services	Telecommunications	Defining end-to-end view business processes for managing telecommunications enterprises.	It describes processes in a 4-level hierarchy. Level 0 processes (enterprise level) are Strategy, Infrastructure and Product, Operations and Enterprise Management.	Industry Consortium	Tele Management Forum (2011)	5	Public

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Y(-shaped)-Computer Integrated Manufacturing Reference Model (Y-CIM)	3	Conceptual	Manufacturing	Supply Chain Management; Product Development Management	Providing a generic representation of how to integrate logistics and engineering business processes (product design) for manufacturing operations.	Y-Shaped model, containing logistics-related processes on the left, engineering-related processes on the right as well as the relationship between the processes. Contain two levels of abstraction.	Academy	Scheer, Jost and Gungoz, 2007	5	Restricted
Control Objectives for Information and Related Technology (COBIT)	3	Detailed	Services	Information Technology Management	Defining best practices (business processes, performance metrics, a preliminary maturity model, guidelines for governance and control) for provision and management of IT services.	COBIT 5 subdivides IT processes in 2 main activities areas: governance and management.	Consultancy	Information Systems Audit and Control Association (ISACA) (2012)	4	Restricted
Value Reference Model (VRM)	3	Detailed	Manufacturing	Neutral	Providing a general classification of business processes of an organization's integrated value chain, including: Enterprise Management, Product Development, Supply Chain Integration and Customer Relationship Management.	VRM contains 3 levels of processes, being level 1 composed by: Plan, Govern and Execute. It does not envision planning and execution of management and supporting processes such as Human Resources and IT. Previously named VCOR.	Consultancy	Value Chain Group (2015)	3	Restricted
Porter Value Chain Model	3	Conceptual	Generic	Neutral	Supporting companies on identifying business processes that enable the creation of value within an organization and the delivery of value to customers.	The model contains 5 main processes for the value chain: Inbound Logistics, Operations, Outbound Logistics, Marketing, Sales, and Service.	Academy	Porter (1985)	2	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Federal Enterprise Architecture Framework (FEAF)	1;3	Detailed	Services	Government	Supporting design and performance improvement of federal governments' enterprise architecture.	The model envisions integration of strategic, business and technology management.	Government	US Office of E-Government (E-Gov) and Information Technology (IT) (2007)	2	Public
Design Chain Operations Reference Model (DCOR)	3	Detailed	Manufacturing	Research and Development Management	Linking to SCOR model defining business processes, performance metrics, and best practices for design-chain management (product development and research and development business processes). (Source: Nyere, 2006)	DCOR contains business processes, practices and performance metrics for R&D and product development processes. Level 1 Processes included in DCOR: Plan; Research; Design; Integrate; and Amend.	Industry Consortium	Supply Chain Council (2010)	2	Restricted
HP Service Management Reference Model (HP SMRM) (based on SCOR)	3	Detailed	Services	E-commerce, e-business, e-services	Defining best practices in terms of IT Management processes, inter-process relationships, and business linkages for the successful development, deployment and support of services in the e-world.	HP SMRM is based on ITIL, CMMI-Dev, and Scaled Agile Framework ("SAFe"). The model contains 3 levels: group of processes, processes and activities. For each process, quality assurance activities are also indicated. There is no indication of KPIs.	Industry	HP (2003)	1	Public
ACORD Capability Model	1;2;3	Detailed	Services	Insurance	Defining standard capabilities and business processes for insurance industries.	It contains three levels: Capabilities, processes, activities. Processes and activities are un-sequenced and sometimes they refer to both words in a same level.	Standards Organization	Jones et al., (2010)	1	Public

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Global Supply Chain Forum (GSCF) Reference Model	3	Conceptual	Manufacturing	Supply Chain Management	Defining cross-functional and cross-enterprise (including the interfaces with suppliers, customers and end-users) business processes to manage the supply chain, and instruct how to map and improve value capturing in the supply chain (using EVA indicator).	Major focus on identifying value to improve the relationship with customers (CRM) and suppliers (SRM). Value is translated into financial indicators (EVA) to align with the company's strategy. It contains 8 key cross-functional processes.	Academy; Research Organization	Global Supply Chain Forum (GSCF) (1998) (LAMBERT et al., 1998)	1	Restricted
Collaborative Planning, Forecasting and Replenishment (CPFR) Reference Model	3	Detailed	Manufacturing	Supply Chain Management	Defining best practices (in terms of activities, and roles and responsibilities) for the collaborative operation of planning and fulfillment processes (planning, forecasting and replenishment) involving multiple trading partners.	It contains 2 levels of abstraction. The first level is "Activities" (Analysis, Strategy and Planning, Demand and Supply Management, and Execution), although they truly represent processes if compared to SCOR model. The second level represent "Tasks", although they represent Activities in reference to SCOR. There are specific reference models for the 4 most common scenarios (retail event collaboration, DC replenishment collaboration, store replenishment collaboration, collaborative assortment planning).	Industry Consortium	Voluntary Interindustry Commerce Standards (VICS) Association (1998)	1	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Industrial Services Reference Model (IRM)	3	Detailed	PSS	Supply Chain Management	Defining business process processes, key performance indicators and best practices to guide Services Providers to operate services in collaboration with their customers' (Manufacturer) supply chain based on the SCOR reference model.	Adapted from SCOR to support services supply chain. It contains 3-level hierarchy (like SCOR): Level 1 - Strategic Process Types; Level 2- Configurations for Services Clusters; Level 3 - Process elements. Level 3 processes define the transition from a generic reference model to a customer specific workflow.	Academy	Gerosa e Taisch (2008, 2009) Osadsky et al. (2007)	1	Restricted
Reference model for collaborative truck fleet management service (Y-CIM and Service-Y)	3	Conceptual	PSS	Truck Fleet Management	Defining processes and activities to guide the collaborative provision of truck fleet management services by truck manufacturers and services' consulting providers based on the Y-CIM and Service-Y reference models.	It integrates Y-Shaped model (containing logistics-related activities on the left, engineering-related activities on the right as well as the relationship between the activities) with Service-Y model (containing service provision activities on the left and service engineering activities on the right, as well as their interrelationship). It contains two levels of abstraction.	Academy	Becker (2008, 2010)	1	Restricted
Product-Service Bundles Procurement Model	3	Conceptual	PSS	Supply Chain Management	Defining business processes for the electronic procurement of product-service bundles to complement SCOR reference model.	This model defines strategic sourcing processes specific for service offers and combine with SCOR reference model. It contains two levels of abstraction.	Academy	Bensch and Schrödl (2011)	1	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
ECOMOD reference processes	3	Conceptual	Services	E-commerce, e-business, e-services	Providing best practices (including a decision network of strategies, a library of reference business processes, a description of concepts, a prototype for mapping business processes to workflows and a glossary) for e-commerce business.	ECOMOD is a project funded by the German National Research Foundation (DFG), for supporting companies, especially small and medium sized companies (SME), with developing e-commerce businesses. It contains an on-line library that comprises 84 reference business processes classified under Procurement and Sales.	Academy	Frank, U (2016)	1	Restricted
Canadian NFC Mobile Payment Reference Model (MPRM)	3	Detailed	Services	Financial services	Establishing a common reference model for mobile payment processes in Canada. This reference model defines and communicates processes, roles, responsibilities and expectations in the form of standards statements.	This reference model was developed as a requirement of the August 2011 Interim Report of the Canadian Federal Government's Task Force for the Payments System Review ("Payment Task Force"). It encompasses the detailed definition of processes at the "activity" level for the complete life cycle of mobile payments.	Industry Consortium; Government	Canadian Bankers Association, 2012	1	Public
ISO/IEC 15504: Information technology -- Process assessment	4	Detailed	Generic	Systems and Software engineering	Defining a generic framework for software process assessment.	Standard for Information technology is also known as SPICE (Software Process Improvement and Capability Determination).	Standards Organization	International Organization for Standardization, 2004	1	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
ISO/IEC 12207: Systems and software Engineering - Software life cycle processes	4	Detailed	Generic	Systems and Software engineering	Establishing a common framework for software life cycle processes that can be referenced by the software industry.	"It contains processes, activities, and tasks that are to be applied during the acquisition of a software product or service and during the supply, development, operation, maintenance and disposal of software products." Source: http://www.iso.org/iso/catalogue_detail?csnumber=43447	Standards Organization	International Organization for Standardization, 2008	1	Restricted
IEC 80001: Application of risk management for IT-networks incorporating medical devices	4	Detailed	Manufacturing	Medical Devices	Defining the roles, responsibilities and activities that are necessary for risk management of IT-networks incorporating medical devices to address safety, effectiveness and data and system security.		Standards Organization	International Organization for Standardization, 2010	1	Restricted
ISO/IEC 20000-1: Information technology -Service management	4	Detailed	Services	Systems and Software engineering	Specifying requirements for the service provider to plan, establish, implement, operate, monitor, review, maintain and improve an SMS. It includes the design, transition, delivery and improvement of services to fulfil agreed service requirements.		Standards Organization	International Organization for Standardization, 2011	1	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (continuation)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
Customer-Chain Operations Reference-Model (CCOR)	3	Detailed	Manufacturing	Supply chain management	Represent sales operations and customer support business processes, performance metrics and practices into a unified structure within SCOR.	The CCOR reference is in a less mature state than other APICS frameworks. It contains 3 levels of process detail: Top Level (types), Configuration Level (categories), Element Level (decompose processes). The fourth level, Implementation (decompose elements) is not scope. Level 1 Processes included in CCOR: Plan; Relate; Sell; Contract; Assist.	Industry Consortium	Supply Chain Council (2010)	1	Restricted
Product Lifecycle Operations Reference-Model (PLCOR)	3	Detailed	Manufacturing	Supply chain management	Represent product lifecycle processes from the first idea to broad adoption in the mass market, performance metrics and practices into a unified structure within SCOR.	Level 1 Processes included in PLCOR: Plan; Ideate; Develop; Launch; Revise; Enable	Industry Consortium	Supply Chain Council (2012)	1	Restricted
SAP R/3 Reference Model	3	Detailed	Generic	Generic	The main purpose of the reference model is to supporting the implementation and configuration of the SAP system. It may also support training of personnel and serve as a blueprint with best practices to support improving the current processes of an organization.	The model is included in SAP System, as well as modelling tools such as ARIS. The main emphasis is on business processes represented by EPC language.	Industry	SAP	2	Restricted

Table I – Business process reference model catalogue (Types: 1- Methodical Business Process Engineering Approaches; 2- Technical Infrastructures for Process Integration and Process Model Interchange; 3- Reference process models; 4- Standards) (conclusion)

Name	Type	Abstraction level	Domain	Sector	Purpose	Description	Origin	Author	Number of citations	Access
ABB Reference Model (under development)	3	Conceptual	PSS	Automation technology	Defining standard service provision processes for the company ABB.	The reference model merges CCOR and ABB standard macro-processes upon a hierarchical structure comprising four levels. This reference model is still under development.	Academy; Industry	Curiazzi et al. (2016)	0	Restricted
JSI Framework for Integrated Supply Chain Management in Public Health	3	Conceptual	Services	Supply Chain Management; Public Health	Defining best practices to solve problems in public health supply chains.	It goes beyond defining processes and includes the organizational aspects of the supply chain, comprising the relationships between actors of the network.	Consultancy; Research Organization	JSI (John Snow Inc.) (2012)	0	Restricted

References

APQC. Cross Industry Process Classification Framework, Version 7.0.2. Disponível em: < <https://www.apqc.org/pcf>>. Acesso em: 30 nov. 2015.

BECKER, J.; BEVERUNGEN, D. F.; KNACKSTEDT, R. The challenge of conceptual modeling for product-service systems: Status-quo and perspectives for reference models and modeling languages. Information Systems and e-Business Management, v. 8, n. 1, p. 33–66, 2010.

BECKER, J.; BEVERUNGEN, D.; KNACKSTEDT, R. Reference Models and Modeling Languages for Product-Service Systems – Status-Quo and Perspectives for Further Research.41st Hawaii International Conference on System Sciences. Anais...2008

BENSCH, S.; SCHRÖDL, H. Purchasing Product-Service Bundles in Value Networks-Exploring The Role of SCOR. Ecis, n. 2011, p. Paper 114, 2011.

CANADIAN BANKERS ASSOCIATION. Canadian NFC Mobile Payments Reference Model. p. 1–133, 2012.

CURIAZZI, R. et al. Process Standardization to Support Service Process Assessment and Re-engineering. Procedia CIRP, v. 47, p. 347–352, 2016.

ECOMOD. Disponível em: <https://www.wi-inf.uni-duisburg-essen.de/FGFrank/ecomod/index.php?lang=en>. Acesso em: 20 mar. 2016.

GEROSA, M.; TAISCH, M. Industrial services reference model1st CIRP Industrial Product-Service System (IPS2) Conference. Anais...2009

HP. The HP IT Service Management (ITSM) Reference Model Transforming IT through IT Service Management. Disponível em: <ftp://ftp.hp.com/pub/services/itsm/info/itsm_rmwp.pdf>.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO/IEC 15504: Information technology - Process assessment. Disponível em: <-https://www.iso.org/obp/ui/#iso:std:iso-iec:15504:-3:ed-1:v1:em>. Acesso em: 15 out. 2016.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO/IEC 12207: Systems and software Engineering - Software life cycle processes. Disponível em: <https://www.iso.org/obp/ui/#!iso:std:43447:em>. Acesso em: 15 out. 2016.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. IEC 80001: Application of risk management for IT-networks incorporating medical devices. Disponível em: <https://www.iso.org/obp/ui/#iso:std:iec:80001:-1:ed-1:v1:em>. Acesso em: 15 out. 2016.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO/IEC 20000-1: Information technology -Service management. Disponível em: <https://www.iso.org/obp/ui/#iso:std:iso-iec:20000:-1:ed-2:v1:em>. Acesso em: 15 out. 2016.

ISACA. COBIT Framework. Disponível em: <https://cobitonline.isaca.org/>. Acesso em: 10 fev. 2016.

IT PROCESS MAPS GBR. Introduction: ITIL Version 3 and the ITIL Process Map V3. Disponível em: <http://ftp.psu.ac.th/pub/itil/introduction_itil_process_map_v3.pdf>. Acesso em: 10 fev. 2016.

JOHN SNOW INC. ABB Reference Model (under development) JSI Framework for Integrated Supply Chain Management in Public Health. Disponível em: <http://www.jsi.com/JSIInternet/>.

JONES, D. F. et al. The ACORD Capability Model. 2010.

LAMBERT, D. M.; COOPER, M. C.; PAGH, J. D. Supply chain management: implementation issues and research opportunities. The international journal of logistics management, v. 9, n. 2, p. 1–20, 1998.

OFFICE OF E-GOVERNMENT & INFORMATION TECHNOLOGY. Federal Enterprise Architecture. Disponível em: <https://www.whitehouse.gov/omb/e-gov/FEA>. Acesso em: 18 mar. 2016.

OSADSKY, P. et al. Improving service operation performance by a cross-industry reference model. IFIP International Federation for Information Processing, v. 246, p. 397–404, 2007.

PORTER, M. E. Competitive advantage: creating and sustaining superior performance. New York: FreePress, 1985.

SCHEER, A.; JOST, W.; GUNGOZ, Ö. A Reference Model for Industrial Enterprises. In: Reference Modeling for Business Systems Analysis. IGI Global, 2007. p. 167–181.

SUPPLY CHAIN COUNCIL. SCOR: Supply Chain Operations Reference Model Version 10.0., 2010a.

SUPPLY CHAIN COUNCIL. Design-Chain Operations DCOR-model, 2010b.

SUPPLY CHAIN COUNCIL. Customer-Chain Operations Reference-Model (CCOR) Version 1.0. p. 3, 2010c.

SUPPLY CHAIN COUNCIL. Product Lifecycle Operations Reference Model (PLCOR), 2012.

TEAM, C. P. CMMI for Acquisition, Version 1.3. Disponível em: <http://www.sei.cmu.edu/reports/10tr032.pdf>. Acesso em: 15 out. 2016a.

TEAM, C. P. CMMI for Services, Version 1.3. Disponível em: <papers3://publication/uuid/0BBB913C-B8C4-425E-8899-661946CB056D>. Acesso em: 25 out. 2016b.

TEAM, C. P. CMMI for Development, Version 1.3. Disponível em: <www.sei.cmu.edu/reports/10tr033.pdf, CMU/SEI-2010-TR-033>. Acesso em: 15 out. 2016c.

TM FORUM. Business Process Framework (eTOM) Release 9. Disponível em: <https://www.tmforum.org/business-process-framework/>. Acesso em: 10 fev. 2016.

VALUE CHAIN GROUP. Value Reference Model (VRM), Version 3 Rev 1. Disponível em: <http://www.value-chain.org/vrm>. Acesso em: 10 out. 2016.

VOLUNTARY INTERINDUSTRY COMMERCE STANDARDS (VICS) ASSOCIATION (1998). Collaborative Planning, Forecasting and Replenishment (CPFR) Reference Model. Disponível em: <http://www.gs1us.org/industries/apparel-general-merchandise/tools-and-resources/cpfr-resources>.

Appendix D - Criteria for the Comparative Analysis of Business Process Reference Model

Table II – Meaning of the levels of adherence of each criteria used for assessing the business process reference models (continues)

Criterion	Meaning		
	0: Not adherent	1: Moderately adherent	2: Totally adherent
Ability of offering support to the definition of a Business Process Architecture			
1. Hierarchical view	It is not represented at hierarchical levels.	It contains hierarchical levels, but does not include activities.	It contains hierarchical levels at least up to the level of activities.
2. End-to-end view	It does not comprise all processes of an organization.	It comprises all processes for a specific functional area (*supply chain,* information technology, acquisition) of the organization.	It comprises all processes of an organization, representing them with a cross-functional perspective.
3. Alignment with strategy	It does not comprise processes that translate the strategic objectives of the organization in achievable criteria.	It comprises processes that translate the strategic objectives of the organization in achievable criteria for a specific functional area of the organization.	It comprises processes that translate the strategic objectives of the whole organization.
4. Key performance indicators (KPIs)	It does not define KPIs for processes.	It defines KPIs for some processes.	It defines KPIs for all processes.
Ability of offering support to the operation of a PSS			
1. Customer understanding	It does not comprise processes for customer and PSS requirements identification.	It comprises processes for customer and PSS requirements identification.	It comprises processes for customer understanding that goes beyond requirements identification, such as co-creation, requirements management during operation, involvement of the customer during PSS development.
2. Partnership	It does not present processes that supports for information exchanging and communication with partners.	It presents processes that provides limited support for information exchanging and communication with partners, or co-creation.	It presents processes that provides support for information exchanging and communication with partners, or co-creation.

Table II – Meaning of the levels of adherence of each criteria used for assessing the business process reference models (conclusion)

Criterion	Meaning		
	0: Not adherent	1: Moderately adherent	2: Totally adherent
Ability of offering support to the operation of a PSS			
3. PSS design and delivery	It does not comprise processes to support the development and delivery of the PSS value proposition.	It comprises processes that support the development and delivery of products or services as separate offerings.	It comprises processes that support the development and delivery of combinations of products and services.
4. Process management	It does not comprise processes that support the integrated management of processes in the organization for enabling continuous improvement of efficiency.	It comprises processes that support the integrated management of processes in the organization for enabling continuous improvement concerning product or services as individual offerings.	It comprises processes that support the integrated management of processes in the organization for enabling continuous improvement for the combination of products and services (PSS).
5. Knowledge management	It does not comprise processes that supports the collection, analysis and interpretation of data from the customer-PSS offering iteration during the use phase.	It comprises processes that provide limited support to the collection, analysis and interpretation of data from the customer-PSS iteration during the use phase.	It comprises global processes for knowledge management that support the collection, analysis and interpretation of data from the customer-PSS iteration during the use phase.
6. PSS Life-cycle and End-of-Contract management	It does not comprise processes that support the end of life (EOL) phase of the PSS, including contract termination, remanufacturing and offering discontinuation.	It comprises processes that partially support the end of life (EOL) phase of the PSS, including contract termination, remanufacturing and offering discontinuation.	It comprises processes that support the end of life (EOL) phase of the PSS, including contract termination, remanufacturing and offering discontinuation.
7. Revenue enabling	It does not comprise processes for costing and billing.	It comprises processes for costing and billing oriented for product or services business models.	It comprises processes for costing and billing oriented for PSS business models.

Appendix E – Excerpts of ImageCO's process model views

Figure I – ImageCO PSS process model: macroprocesses in VAC (level 1) (created by the author)

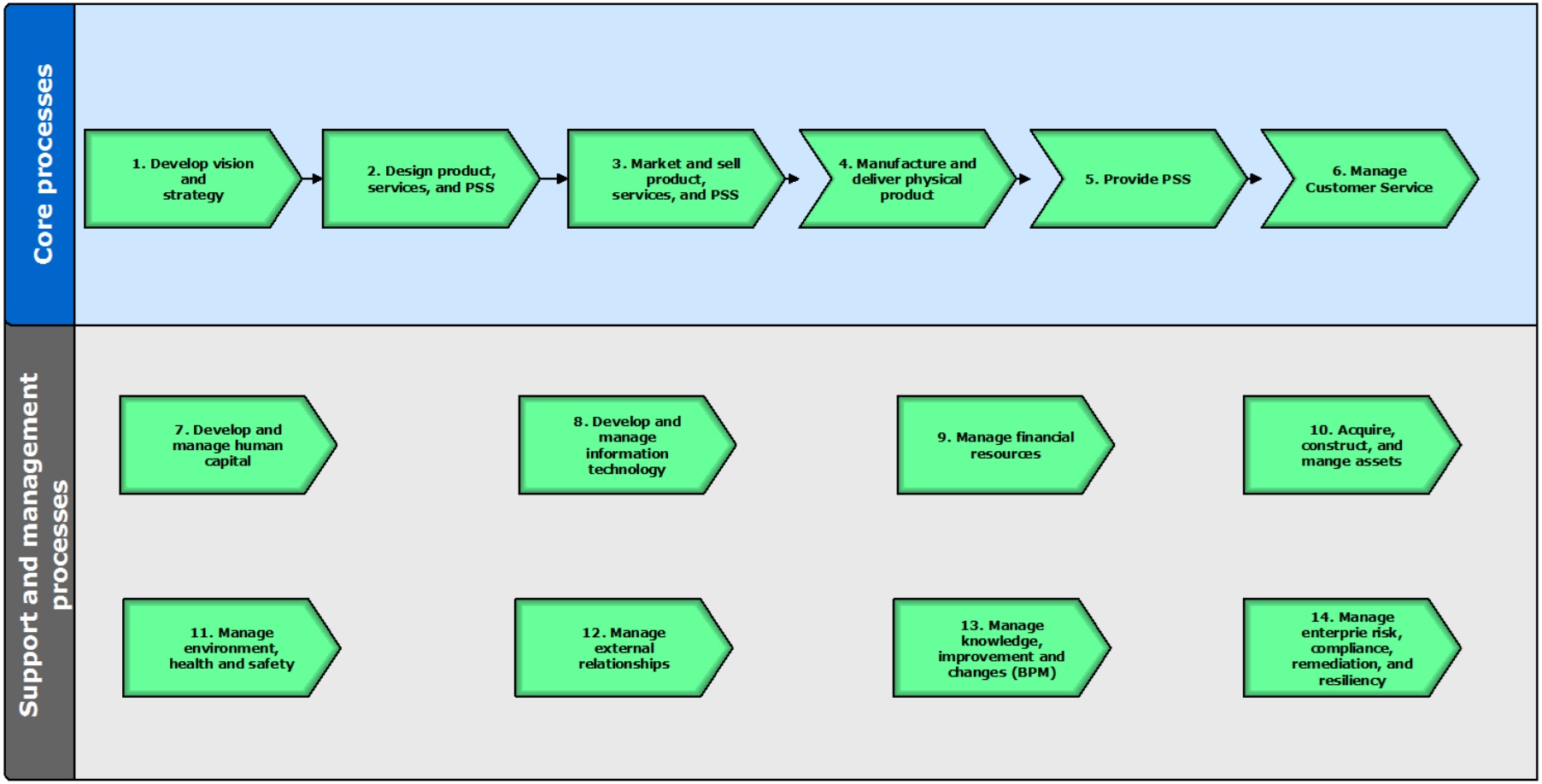


Figure II – ImageCO PSS process model: processes in VAC (level 2) (created by the author)

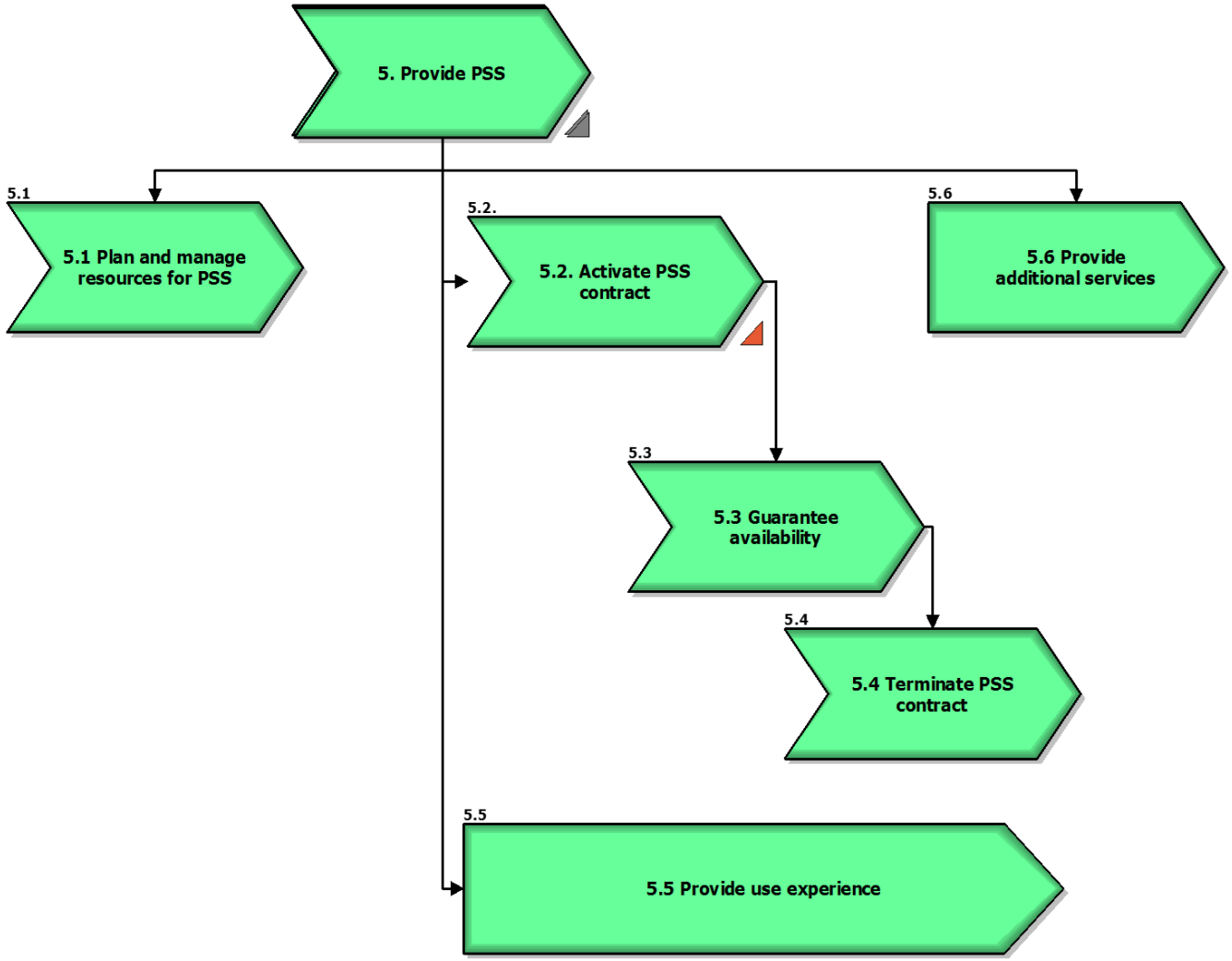


Figure III – ImageCO PSS process model: subprocesses in VAC (level 3) (Green: subprocesses; Yellow: People aspect (organizational unit); Red: Performance indicators aspect) (created by the author)

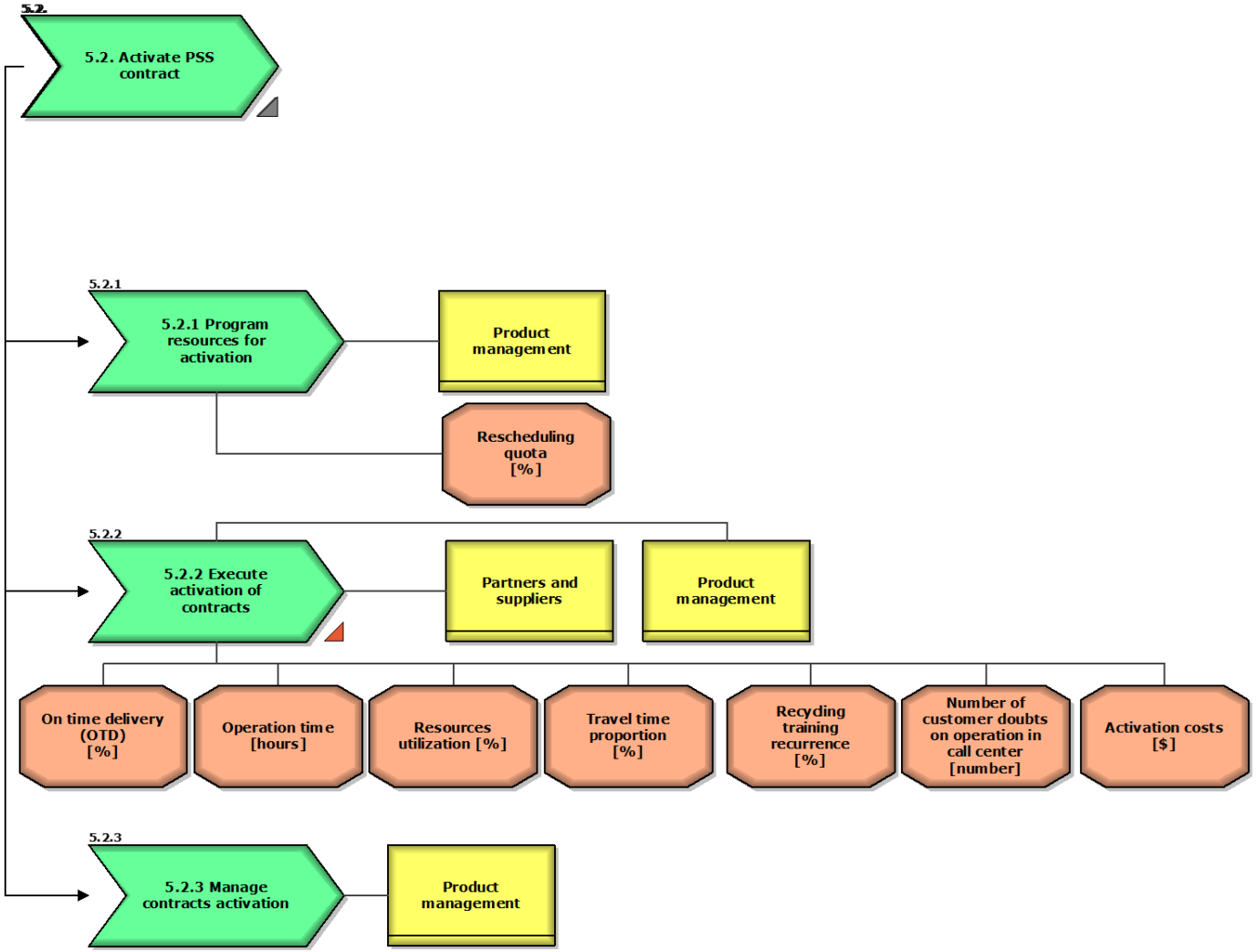


Figure III – ImageCO PSS process model: activities in e-EPC (level 3) (Green: activities; Yellow: People aspect (role); Purple: events; Gray: interfaces with other processes) (created by the author)