ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

MÁSTER EN INGENIERÍA INDUSTRIAL
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INFLUENCE OF CONTEXTUAL FACTORS IN THE DEVELOPMENT OF FUTURE PRODUCT-SERVICE SYSTEMS

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Madrid
Junio 2018

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Influence eof contextual factors on the development of future PSS

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FACTORES CONTEXTUALES EN EL DESARROLLO DE FUTUROS SISTEMAS PRODUCTO-SERVICIO

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RESUMEN DEL PROYECTO

En un mundo globalizado y continuo cambio, las empresas se enfrentan a cambios disruptivos debido principalmente a la digitalización (Albach, Meffert, Pinkwart, & Reichwald, 2015, pp. 3–21; Kagermann, 2015, pp. 23–45). Para mantenerse al día con las demandas del Mercado, buscan la innovación mediante el desarrollo de nuevas soluciones para los clients que combinan productos físicos y servicios intangibles (Baines et al., 2017; Costa, Patr, Morelli, & Magee, 2017). La transformación de una organización que pasa de ser un fabricante a proporcionar servicios especializados es un gran desafío (Baines et al., 2017, p. 3).

Los Sistemas Producto-Servicio (PSS) son una muestra de *servitización*. Se trata de una propuesta de mercado (producto) que incorpora servicios adicionales (Baines et al., 2007, p. 1543). Los modelos PSS son soluciones sostenibles con ventajas tanto para proveedores como para consumidores. Sin embargo, varias organizaciones tienen dificultades para pasar de una orientación de "producto puro" a una perspectiva de Sistema de Producto-Servicio (Pezzotta et al., 2013, p. 1).

Existen muchos factores a tener en cuenta para implementar con éxito un PSS. El tiempo de análisis pasa de un breve período centrado en la actividad dentro de la empresa, a un escenario a largo plazo que cubre no solo la fase de producción, sino también el uso de este producto. El éxito de un PSS depende de factores que generalmente son parte del proceso de diseño (Morelli, 2006). Para anticipar cambios futuros relacionados con estas soluciones, es necesario identificar, analizar y pronosticar factores contextuales durante esta fase.

Basada en una investigación de literatura, el objetivo de este proyecto es encontrar influencias externas en los Sistemas Producto-Servicio, determinar cómo se desarrollarán con el tiempo y cómo interactúan con el PSS. Todo esto permitirá a las empresas adaptar sus productos a los cambios futuros durante la fase de diseño. Para lograr este objetivo, se desarrollará un procedimiento de planificación para apoyar a los diseñadores basado en una extensa investigación. Este procedimiento incluye el uso de herramientas existentes que son útiles para el proceso de planificación.

CONTEXTUAL FACTORS ON THE DEVELOPMENT OF FUTURE PRODUCT-SERVICE SYSTEMS

In a globalized, rapidly changing world, companies face disruptive change due to digitalization (Albach, Meffert, Pinkwart, & Reichwald, 2015, pp. 3–21; Kagermann, 2015, pp. 23–45). In order to keep up with market demands, they seek innovation by developing new solutions to the clients that combine physical products and intangible services (Baines et al., 2017; Costa, Patr, Morelli, & Magee, 2017). The transformation of an organization from being a manufacturer to provide specialized services is a big challenge (Baines et al., 2017, p. 3).

Product-Service System (PSS) is a servitization sample. It is a market proposition (product) that incorporates additional services (Baines et al., 2007, p. 1543). PSS models are sustainable solutions with advantages for both suppliers and consumers. Nevertheless, several organizations have difficulties transitioning from a "pure product" orientation towards a Product-Service System perspective (Pezzotta et al., 2013, p. 1).

There are many factors to take into account to implement successfully a PSS. The time of analysis shifts from a short period focused on the activity within the firm, to a long-time scenario that covers not only the production phase but also the usage of this product. The success of a PSS depends on factors that are usually part of the design process (Morelli, 2006). In order to anticipate future changes concerning these solutions, it is necessary to identify, analyze and forecast contextual factors during this phase.

Based on a literature research, the goal of this thesis is to find external influences on Product-Service Systems, determine how they will develop over time and how they interact with the PSS. All of this will allow companies to adapt the products to future changes during the design phase. For this aim, a planning procedure to support designers is developed based on an extensive research, including existing tools that are useful for the planning process.

2 Introduction

This chapter consists of five sections: a short presentation of the topic (chapter 2.1), a description of the motivation (chapter 2.2), a statement of the objective of the thesis and the research questions (chapter 2.3), a presentation of the methodology (chapter 2.4), and the structure of the work (chapter 2.5).

2.1 Initial situation

In a globalized, rapidly changing world, companies face disruptive change due to digitalization (Albach et al., 2015, pp. 3–21; Kagermann, 2015, pp. 23–45). In order to keep up with market demands, they seek innovation by developing new solutions to the clients that combine physical products and intangible services (Baines et al., 2017; Costa et al., 2017).

The transformation of an organization from being a manufacturer to provide specialized services is a big challenge (Baines et al., 2017, p. 3). Product-Service System (PSS) is a *servitization* sample. It is a market proposition (product) that incorporates additional services (Baines et al., 2007, p. 1543). PSS models are sustainable solutions with advantages for both suppliers and consumers. Nevertheless, several organizations have difficulties transitioning from a "pure product" orientation towards a Product-Service System perspective (Pezzotta et al., 2013, p. 1). Several advantages come with PSS:

- The growth of sustainable revenues and product innovation (Vezzoli, Ceschin, Diehl, & Kohtala, 2015).
- The improvement of responses to customer needs (Ostrom et al., 2010).
- The reduction of sensitivity to price-based competition (Malleret, 2006).
- The decrease of the cash flow volatility (Brax, 2005, p. 142).
- The competitive advantage (Gebauer & Friedli, 2005, p. 72).
- The market share gain and customer loyalty enhancement (Corrêa, Ellram, Scavarda, & Cooper, 2007, pp. 448–449).

Lockett, Johnson, Evans, & Bastl (2011, p. 294) summarize these benefits by classifying them into three groups: revenue enhancing benefits, value-enhancing benefits and maintaining a competitive advantage in the future.

There are many factors to take into account to implement a PSS. The time of analysis shifts from a short period focused on the activity within the firm, to a long-time scenario that covers not only the production phase but also the usage of this product. The success of a PSS depends on factors that are usually part of the design process (Morelli, 2006). In order to anticipate future changes concerning these solutions, it is necessary to identify, analyze and forecast contextual factors during this phase.

2.2 Motivation

The complexity companies are facing nowadays drives focus to the development process of Product-Service systems cycle management. The changes caused by these sequences include iterations and recursions on the development process. This scenario leads to an inefficient development process. Therefore, the correct identification of the factors influencing the Product-Service Systems will help improve the core design process (Langer & Lindemann, 2009).

As previously mentioned in the initial situation (chapter 2.1), the identification and forecast of influence factors on PSS is a significant challenge. This factors analysis must be reviewed with regard to the solutions given in the literature. Based on the findings extracted from literature, conclusions can be drawn on how to develop a new PSS taking into account the context in which these factors find themselves.

Due to the rising complexity of product development, the importance of this problem will continue to increase in the future. As a result, this topic is of high relevance to both research and industry. Even though many literature sources deal with supply networks in product manufacturing, there is little information on the context of PSS (Lockett et al., 2011). The planning phase of a PSS involves decision making under high uncertainty. Hence, methodological support for designers is critical. Early information about future requirements and influences help decision making and successful PSS development.

Various areas of knowledge attend the purpose of supporting engineers and stakeholders along the innovation process. In future PSS strategic planning, a reliable procedure is needed in order to prioritize all innovative ideas. The identification, understanding, and description of these factors can help in the decision-making process through the evaluation of their influence. Thereby, products should be planned with anticipation and all lifecycle stages should be considered before their implementation (Hepperle, Langer, Scherer, Schwetz, & Lindemann, 2010, p. 1100).

2.3 Objective and research questions

The initial situation described (chapter 2.1), and the following motivation (chapter 2.2) already outline the objective of this study. This section intends to draw the boundaries of the conducted research.

This research focuses firstly on finding the existing factors' context and its influence on the Product-Service Systems future requirements. In order to achieve this, this thesis concentrates on the assortment and classification of circumstances and factors representing the external context of PSS. These factors usually have a cyclic behavior and their forecast is not an easy task. Firms have to deal with short innovation cycles and need to be able to deliver their products in a quick manner (Schenkl, Behncke, Hepperle, Langer, & Lindemann, 2013, p. 918).

The derived system should be clear and easy to follow for all concerned stakeholders. This thesis intends to provide a theoretical procedure that supports the finding and documentation of contextual influences on PSS product development.

This thesis also aims to aid the understanding of key influences affecting PSS and the prediction of their future behavior. This procedure intends to support designers on the initial product design stages though the promotion of the early adaption of future customer's requirements to the product.

Different tools have been analyzed in order to be able to select the most appropriate ones in every step of the presented procedure. This thesis scope not only studies the effect of various influences, but also tries to provide a standardized guidance on how to assign the different activities in the interdisciplinary product development.

The ultimate objective of this thesis would be to confirm the potential use of the developed procedure by its application to a real use-case. However, the defined scope only assumes its validation in an academic framework. Since there is no practical example given, this thesis represents the basis for future empirical study as well as for the analysis of the model.

The outcome of this thesis should provide helpful for designers in order to manage design processes in a more efficient manner through the understanding and gathering of contextual factors information and influences on the product. This can only be achieved through the definition of a structured and standard procedure aimed to be used by product developers.

Several research questions can be extracted from the aforementioned thesis objectives. These questions will be discussed in the following chapters through the usage of the research methodology which will be described in the following chapter.

According to the observations addressed before, the following research questions are formulated:

Table 2-1: Research Questions overview

RQ1	What is the state of the art on contextual factors and PSS?
RQ2	How can the identified contextual factors be clustered and processed, so they serve as support for designers in their future PSS planning?
RQ3	How are these influences interconnected with the PSS?

Firstly, RQ1 is aimed towards the necessity of a current literature review. As many factors as possible should be identified along with elements such as requirements, PSS development design methodologies and studies about product generations.

Furthermore, RQ2 focuses on the systematic organization of these factors in a useful manner to PSS designers. In order to be able to deal with the large quantity of gathered factors, these should be clustered accordingly in order to provide a simplified standardized use to designers.

Finally, RQ3 suggests the development of an interconnected procedure that supports the whole planning of the future PSS development. This interconnection allows throughout the process both traceability, needed to maintain transparency, and the availability of information to all stakeholders.

2.4 Methodology

This chapter explains the research methodology applied on this thesis. The utilization of a research methodology favors an effective approach to clarifying the research questions and usually drives to an enhancement of the research outcomes. In this case, the followed research methodology is the Design Research Methodology (DRM) by Blessing and Chakrabarti. This research methodology aims to support designers in the process of research, making it accurate and useful (Blessing & Chakrabarti, 2009, p. 13). Other concepts like the Matrix Method of Literature Review are also relevant for this work. This concept could be applied at the beginning of the research when the researcher's knowledge is scarce. It provides a tool to organize the process of a literature review, guaranteeing its objective nature (Klopper, Lubbe, & Rugbeer, 2007, p. 262).

The DRM consists of four stages: Research Clarification, Descriptive Study I, Prescriptive Study and Descriptive Study II. DRM should not be understood as a collection of stages and techniques that should be linearly performed as this would have adverse consequences. Hence, working in parallel is highly recommended (Blessing & Chakrabarti, 2009, p. 17). The individual procedure stages of the DRM are explained along with the elements composing them and their interrelations (see Figure 2-1).

- Research Clarification (RC): A description of the initial situation, as well as the desired one, are developed during this phase. This objective clarification, intends to confirm or dismiss the hypothesis that triggered the research.
- Descriptive Study I (DS-I): In this stage, the initial description leads to a more detailed picture of the most critical factors, which then allows an increased understanding on the design elements.
- Prescriptive Study (PS): To develop a foundation for design improvement taking into account the desired output and the available inputs.
- Descriptive Study II (DS-II): To identify the eligibility of using the foundation developed in the previous stage in a specific situation, and to measure its success if applied. It is usually completed with empirical studies such as use cases.

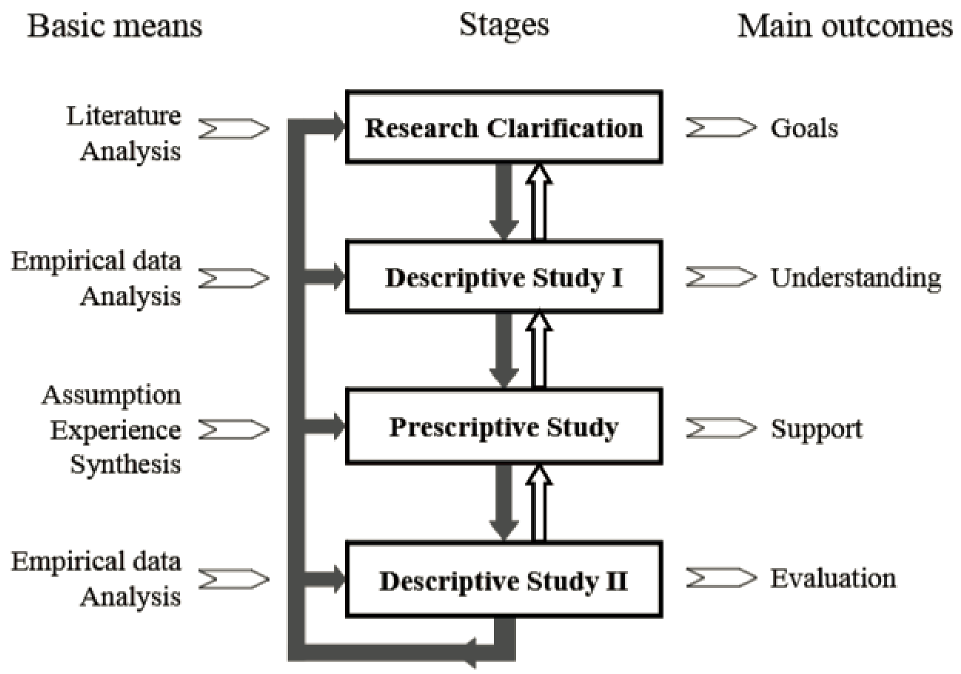

Figure 2-1: DRM framework ((Blessing & Chakrabarti, 2009, p. 15)

Not all research projects include every stage explained before. Depending on their objective, they could focus on a deeper study of a particular one. For instance, Blessing & Chakrabarti (2009) propose seven different types of studies depending on the way of dealing with the four stages (see Table 2-2). The decision of conducting a comprehensive or review-based study generally depends on the researcher's general resources and time availability. The review-based study concentrates purely on the review of the existing literature, and the comprehensive study incorporates results originated by the researcher. The initial study is the last step of a project, which summarizes the conclusions and provides a guide for future research.

Table 2-2: Types of design research projects, modified (Blessing & Chakrabarti, 2009, p. 18)

Research Project type	**Research Clarification**	**Descriptive Study I**	**Prescriptive Study**	**Descriptive Study II**
1	Review-based	Comprehensive		
2	Review-based	Comprehensive	Initial	
3	Review-based	Review-based	Comprehensive	Initial
4	Review-based	Review-based	Review-based Initial / Comprehensive	Comprehensive
5	Review-based	Comprehensive	Comprehensive	Initial
6	Review-based	Review-based	Comprehensive	Comprehensive
7	Review-based	Comprehensive	Comprehensive	Comprehensive

Project types one to four are focused on one stage (DS-I for project types one and two, PS for project type three, and DS-II for project type four) through the conduction of only one comprehensive study. They are recommended for PhD dissertations. Project types five and six include two comprehensive studies in two different stages. Finally, three comprehensive studies are required for project seven, distributed in three stages. This type of project is useful whenever the scope is very specific.

This thesis will focus on research project type three according to Table 2-2. No iterations were required, and all steps were performed in parallel. In the following table, the individual procedure stages of the DRM and their relation to the contents of this thesis are shown. Table 2-3 presents a detailed summary essential information regarding the DRM applied to this thesis.

Table 2-3: Activities of the research project type 3 regarding this thesis

Methods	**Stages**	**Main outcomes**
Literature review Analysis and problem formulation	Research Clarification	Objective and research questions Literature review methodology set-up
Literature review	Descriptive Study I	Definition of basic terms and concepts Understanding the basics of the topic Research gap definition (Literature Review Matrix)
Adaptation of methodical approaches and summary to overall concept	Prescriptive Study	Development of the procedure Analysis of the different tools available for every stage
Discussion	Descriptive Study II	Evaluation and limitations of the developed procedure Identification of research needs in the outlook

1. Research Clarification (RC): This first step of the DRM consists on the definition of the problem based on the literature review. The topic should be of interest in both academia and industry. This is reflected in chapter 2.2. The scope of this thesis is described in chapter 2.3. One of the criteria for the success of the work carried out in this thesis is the complete response to the research questions presented in this chapter 2.3. In chapter 3.1 the literature review methodology is presented.
2. Descriptive Study I (DS-I): On the second stage of the DRM, a literature analysis was conducted which includes both comprehensive studies from third parties, as well as sources focusing on individual aspects of the topic. This section aims to provide an understanding of the topic, it is divided into two sections. On one hand, chapter 3.2 defines the basic terms and concepts. On the other hand, chapter 3.3, and chapter 3.4 contain a literature review, where several approaches are presented in order to deal with the contextual factors influence on the future PSS development. After concluding the literature review, a research gap is identified and clarified in chapter 3.5.
3. Prescriptive Study (PS): The prescriptive study of the DRM deals with the development of a solution. In this case, being a procedure to identify, prioritize and forecast the influence of context factors on the future PSS development (chapter 4). In order to achieve this solution, the information gathered in the previous step is used as a basis. Every stage of the proposed procedure contains

an overview of the available tools needed to complete it, as well as an analysis in order to provide designers with a summary for selecting the suitable options in every step of the procedure.

4. Descriptive Study II (DS-II): In the second descriptive study, the developed solution resulting from the previous step is analyzed in order to evaluate its success. In this thesis, there was no time to conduct a case study and evaluate the methodology through an industry example. For this reason, applicability is not assured. However, an academic evaluation is provided in the discussion. The outlook draws further research needs regarding the analysis of influences in the development of future PSS.

2.5 Structure of the thesis

At the beginning of this thesis, it is important to have a clear understanding of the topic. For this reason, the initial situation is presented (chapter 2.1), the motivation explained (chapter 2.2), and the objective and research questions clarified (chapter 2.3). Additionally, the selected methodology (chapter 2.4) and the structure of the work (chapter 2.5) complete chapter 2.

Chapter 3 discusses the theoretical background and state of the art of the topic. The consistency of the results is ensured by a systematic literature review with a detailed research plan (chapter 3.1). In addition to the definition of important terms (chapter 3.2), both the presentation of different Product-Service System design methodologies (chapter 3.3) and the characterization of the contextual factors is undertaken (chapter 3.4). Finally, a literature review matrix that presents the research opportunity is developed (chapter 3.5).

Chapter 4 presents the development of a procedure, which is the core of this thesis. By specifying a standard procedure, the product designers are provided with an orientation aid for the planning of future PSS. Chapter 4.1 discusses the importance of the procedure requirements' clarification and presents an overview of the procedure. Once the model is presented, the elements composing it and the proposed tools to complete them are described (chapter 4.2, chapter 4.3, and chapter 4.4).

The validity and limitations of the model are explained in chapter 5. Here it will be checked whether the results obtained will be able to support the designers in solving the stated problem. Finally, a summary of the thesis contents (chapter 6.1) are presented along with a list of the topics that might need further research in the field of contextual factors and planning (chapter 6.2).

Figure 2-2 represents the structural design of this thesis. In addition, the representation of the chapters shows their interdependencies. In this given case, chapter 2, chapter 5, and chapter 6 refer to the entire thesis. However, chapter 3 acts as a link between chapter 2 and chapter 4, and its output is necessary to complete chapter 4.

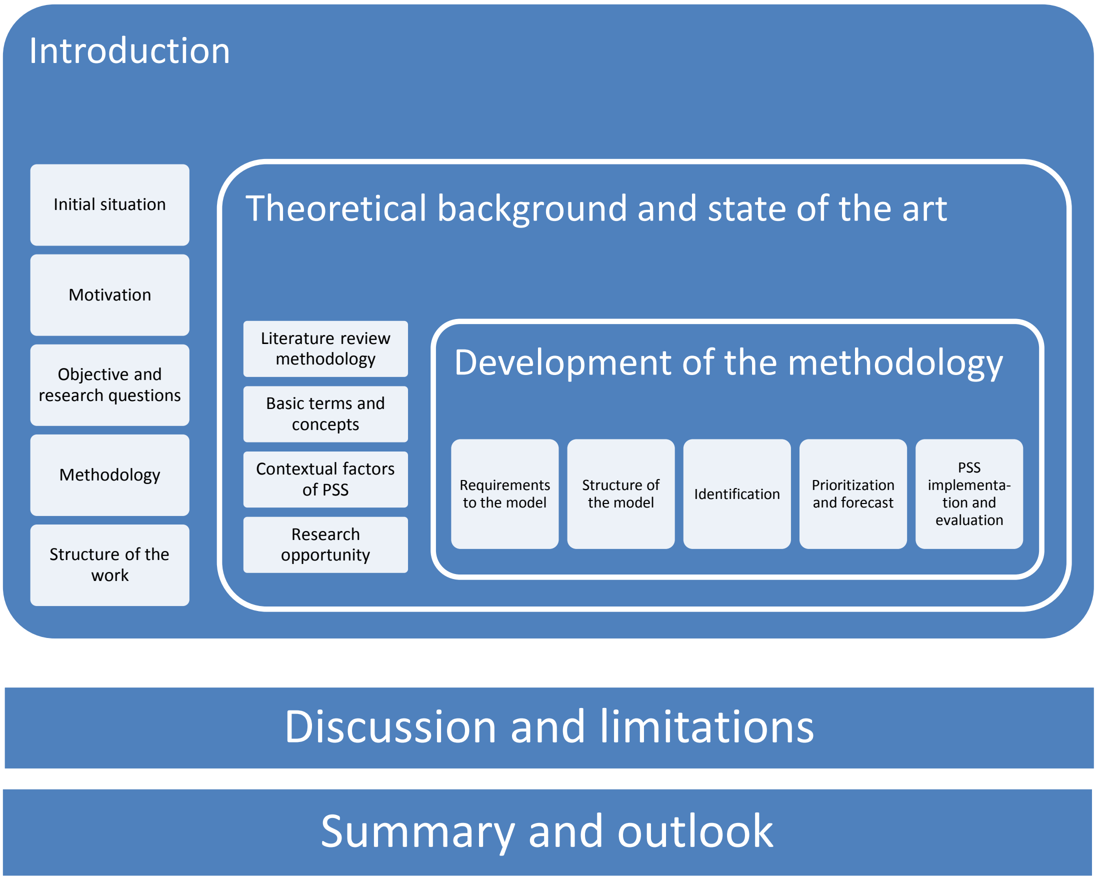

Figure 2-2: Structure of the thesis

3 Theoretical background and state of the art

The aim of this chapter is to grant a common understanding of the topic. For this purpose, this chapter revises the present state of research, and serves as the academic framework for the principal subject of this thesis.

Initially, the basis for the conducted literature review are stated (chapter 3.1). After that, key terms and important concepts for this work are explained and distinguished from each other (chapter 3.2). This is followed by the review of Product-Service System design methodologies (chapter 3.3), and the characterization of the contextual factors of PSS (chapter 3.4). Finally, the research opportunity is identified (chapter 3.5).

As a whole, this chapter outlines the content and nature of information readily available and shows the importance of previous work. It includes the summary of the arguments and ideas of different authors about the study topic. This review is the foundation used for the future development of a proposed procedure for the design of future PSS.

3.1 Literature review methodology

As Wellington, Hunt, & Mcculloch, 2005, (p. 87) explain "reviewing the literature involves searching, collecting, prioritizing, reading with a purpose and seeking out key issues and themes, and then presenting and discussing these critically."

Following this idea, the review conducted in this thesis started with the discrimination of appropriate articles. In order to collect them in an efficient way, a research strategy as well as a prioritization criterion were established. The critical reading of these articles comprises the basis of this chapter.

Figure 3-1 illustrates the six stages followed in the literature review.

1. Choosing a review topic: The topic of this thesis is how context factors affect the development of future PSS. To avoid a long or superficial review, research questions were stated to help narrow the scope and kick off the research with a focused topic.
2. Searching articles: The next step after determining the review topic is the identification and collection of useful information. In order to do that, it is important to structure the research in a systematic manner.
3. Filtering criteria: In order to decrease the large number of initial results in the research, some filters are applied to screen the appropriate studies.
4. Extracting the data: Once the most relevant sources are identified, they are exported into the Mendeley software for future reading.
5. Analyzing and synthetizing: As an initial guide, abstracts are used to classify articles into clusters according to the Literature Review Matrix.

6. Presenting results: The results of the literature review are graphically represented in the Literature Review Matrix, allowing to identify a lack of research on the topic.

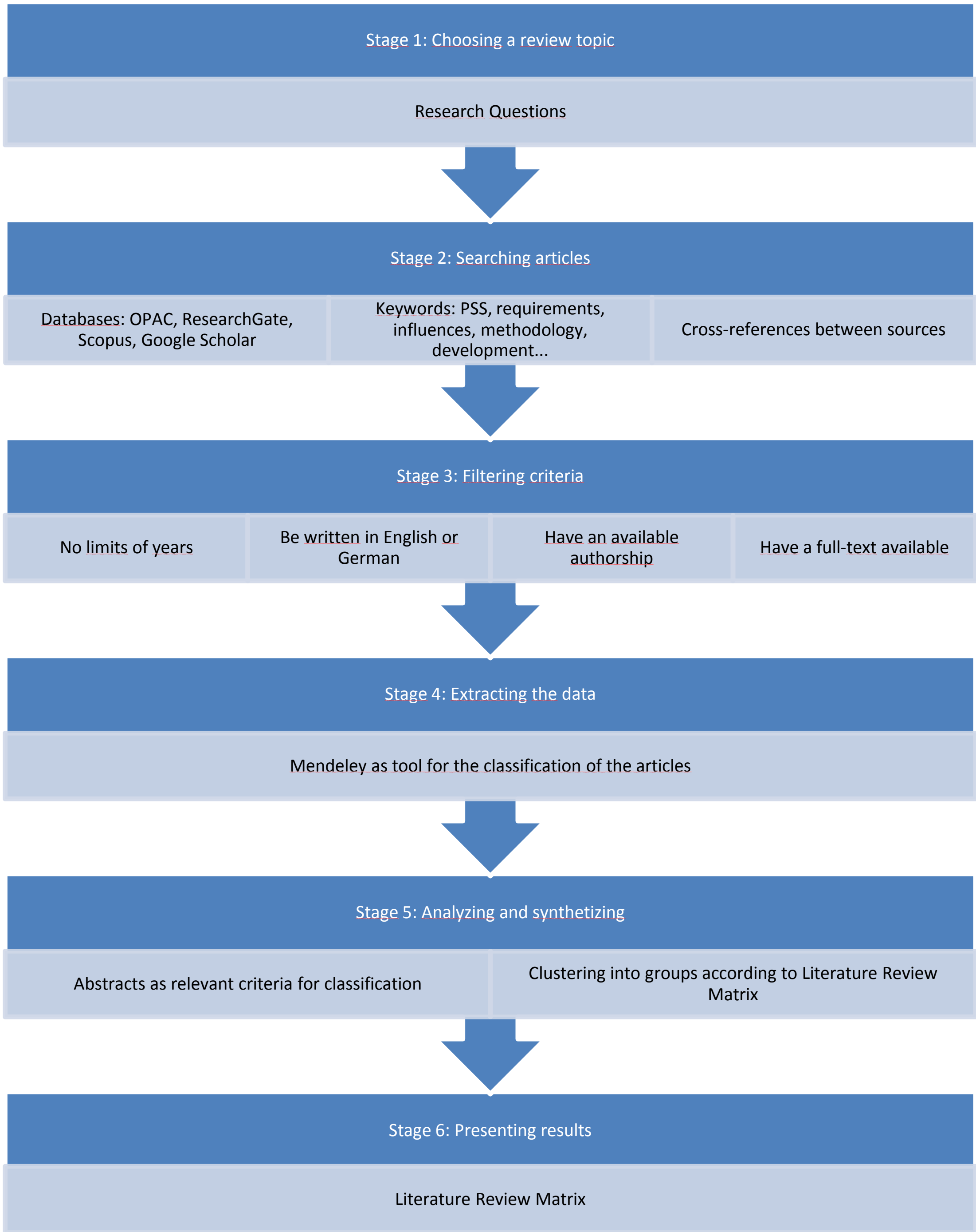

Figure 3-1: Stages followed in the literature review

Table 3-1 collects the strategy followed in the literature review regarding search terms. The combination of search terms helps to simplify the research. The three principal topics searched are Product-Service Systems, Influences, and Design methodology.

Table 3-1: Research Strategy Plan for the literature review

	AND		
OR	**Search Term 1**	**Search Term 2**	**Search Term 3**
	Product-Service Systems	Influences	Design Methodology
	Servitization	Contextual factors	Tools
	Service solutions	Requirements	Planning

3.2 Basic terms and concepts

This chapter intends to define the fundamental concepts that arise from the literature review and which are essential for the development of the next chapters. In this thesis, terms with possible different meanings depending on the context are used. In order to create a common understanding of the topic, they are defined in this chapter.

3.2.1 Requirements

Requirements define the properties of the product to be developed (Grande, 2014, p. 5). In the specialized literature of mechanical engineering, requirements are defined as technical development goals and desired product properties (Ponn & Lindemann, 2011, p. 24). IEEE Stand. Gloss. Softw. Eng. Terminol. (1990) defines the term "requirement" as follows:

- A condition or ability required by a person or the system itself for problem solving or goal achievement (IEEE Stand. Gloss. Softw. Eng. Terminol., 1990, p. 62).
- A condition or ability that a system or system component must meet or have to meet in order to fulfill a contract, standard, specification, or other formally-prescribed document (IEEE Stand. Gloss. Softw. Eng. Terminol., 1990, p. 62).
- A documented representation of a condition or property according to the first two points (IEEE Stand. Gloss. Softw. Eng. Terminol., 1990, p. 62).

According to (Pohl & Rupp, 2010, p. 16), requirements are divided into three categories:

- Functional requirements include functional, behavioral and structural requirements and define the functionality of the product (Pohl & Rupp, 2010, p. 16).
- Quality requirements relate to the performance, availability, reliability, scalability or portability of the system to be developed. They have an important influence on the design of the product structure (Pohl & Rupp, 2010, p. 16).
- Constraints limit the design of a new product. The solution space is restricted because designers do not have an impact on constraints (Pohl & Rupp, 2010, p. 16).

The gathering of all requirements is a significant step in the development of a product (Feldhusen & Grote, 2013, p. 320). It takes place at the beginning of the development process when there is a large number of requirements arising from a broad diversity of sources (Ponn & Lindemann, 2011, p. 1).

The collection of requirements represents the starting point of every development project. According to Lindemann (2009), a PSS can only be successful if all development requirements are known at an early stage. In order to gather them, their sources should first be recognized. Then, it is advisable to determine the relationships between them to avoid double counting and to identify conflicting goals.

Goal planning is usually supported by a complete requirement description (Lindemann, 2009). Likewise, Vogel-Heuser, Lindemann, & Reinhart (2014) sustain that one of the failure drivers for development projects is the inaccurate requirements specification, especially, the poor forecasting and estimation of future needs. The later an error is identified, the greater the impact on the project cost. Requirements in PSS have a cyclical behavior, hence, they are constantly changing, so their implementation should be taken into account during the entire innovation process and not only in the early design phase (Vogel-Heuser et al., 2014).

Stakeholders represent the principal source for the collection of requirements (Pohl & Rupp, 2015, p. 4). A complete requirement list is crucial for successful product development. Requirements can be originated both from internal and external sources of the company. The grouping of requirements into classes helps to classify them according to their importance in the development process.

These requirements classifications are used in several projects and by all stakeholders so it is important to have a well-documented, updated database of requirements (Lindemann, 2009). Lindemann (2009) makes a distinction between the collection of implicit and explicit information.

Explicit requirements are usually considered by the stakeholder, and implicit requirements are not immediately related to the customer but should be identified for market success. Explicit information can be systematically evaluated using techniques such as mind mapping, action networks and cause-impact analysis. One way to acquire the implicit information is through the use of questioning techniques. The use of the right collection tools helps to identify all requirements. Specifications and uses of these tools are described in chapter 4.2.1.

Requirements are dependent on each other as well as on other elements, i.e. contextual factors. Success in a development project is achieved through the implementation of the requirements coming from clients and stakeholders, that influence the complete innovation process (Vogel-Heuser et al., 2014). The documentation of the requirements, for example in a list, provide straightforward access to all stakeholders during the whole product development (Lindemann, 2009, p. 106).

Structured clusters of the most relevant requirements help in the development of future designs. Specifications are prone to constant variation, so these compilations must be continuously updated. These checklists should include the most important requirements of products divided into different categories in order to facilitate the identification of the most important elements.

Additionally, Berkovich, Leimeister, Hoffmann, & Krcmar (2014) identify problems regarding requirements and PSS development in their work. Hence, they propose a requirements data model (RDMod) for specific PSS requirements. This model describes different types of requirements and the relationships among them, and focuses on the classification, traceability, and resolution of conflicts.

The applicability of the methodology was confirmed by experts in the industry (Berkovich et al., 2014, p. 161). The model enables the recording of the customer and stakeholder requirements to the PSS in an initial stage, and later their specification during the development phases. The data model defines which requirements have to be drawn out, how they connect to both the customer and the designer of the PSS, and how they match the different phases of the development process (Berkovich et al., 2014, p. 183). The model is employed for reference modeling and works as an initial solution for the development of more specific models. It represents a general arrangement of requirements for PSS, without focusing on particular requirements of a concrete company. Hence, it can be adopted as a basis for the development of data models adapted to specific application conditions (Berkovich et al., 2014, p. 183). The data model includes five levels of abstraction that follow the phases of the development process (see Figure 3-2).

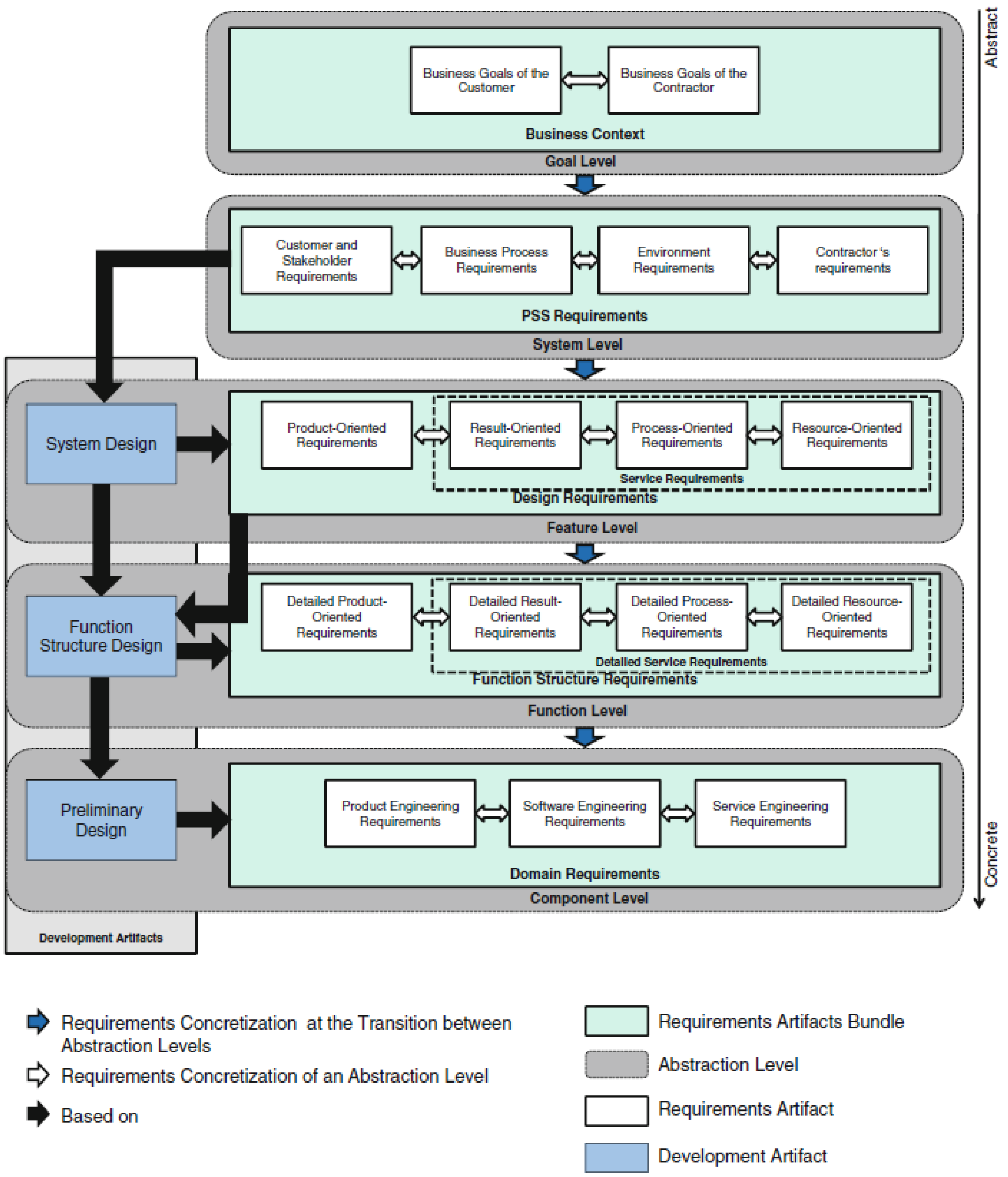

Figure 3-2: Requirements data model (Berkovich et al., 2014, p. 169)

The model for the requirements of PSS developed by Berkovich et al., (2014) consists of five levels of abstractions that match the phases of the development process: goal level, system level, feature level, function level, component level, and also by support activities such as conflict detection and resolution, creation of the functional structure, assignment of the requirements to components, concretization of requirements, and refinement of functions.

The feature level of this model identifies the requirements of the products and services that constitute a PSS. It is composed of five elements: the development system design and four requirements elements (result-oriented, process-oriented and resource-oriented).

- System design: This part combines the requirements to the PSS, managing the technical products, the hardware, software, and services of which the PSS consists. It includes material and immaterial elements of the PSS. The system design is determined by the development activities and consist of two parts: system context, and functional structures (Berkovich et al., 2014, p. 171).
- Product requirements: Specification of the hardware and software requirements (see Figure 3-3). It includes technical functionality and behavior, legal requirements, economic requirements, and quality (Berkovich et al., 2014, p. 171).

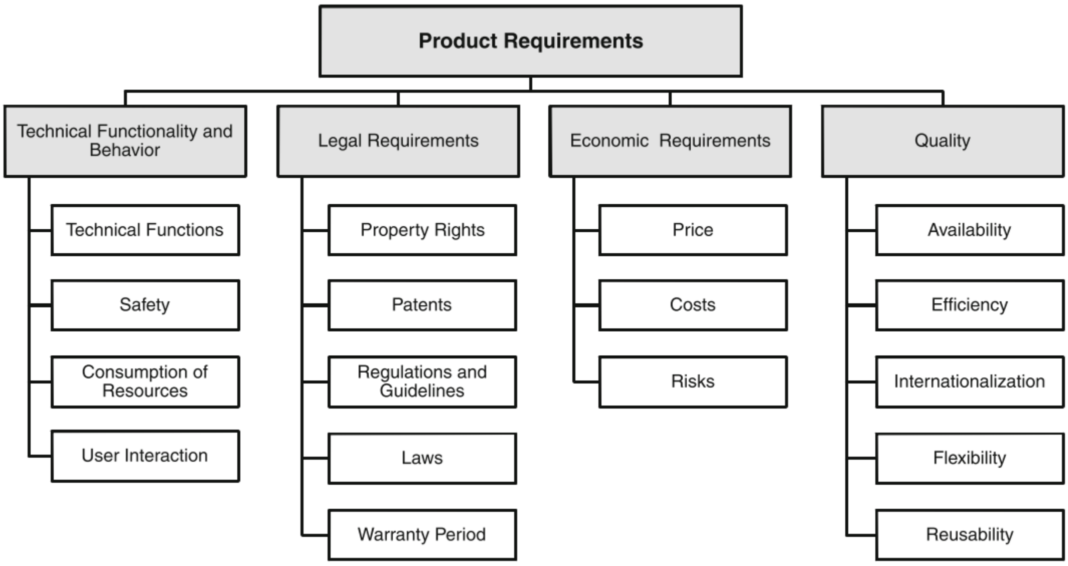

Figure 3-3: Taxonomy of the product requirements (Berkovich et al., 2014, p. 172)

- Result-oriented requirements: The material and immaterial outcome of the services. This element depends fully on the particular PSS being developed, so no taxonomy is presented for this section (Berkovich et al., 2014, p. 171).
- Process-oriented requirements: They provide information on the service design and its activities (see Figure 3-4). It includes process design (activities for the development of the product), interaction (activities that connect the provider and the customer), timing (availability of the product), and reliability (quality management) (Berkovich et al., 2014, pp. 171–172).

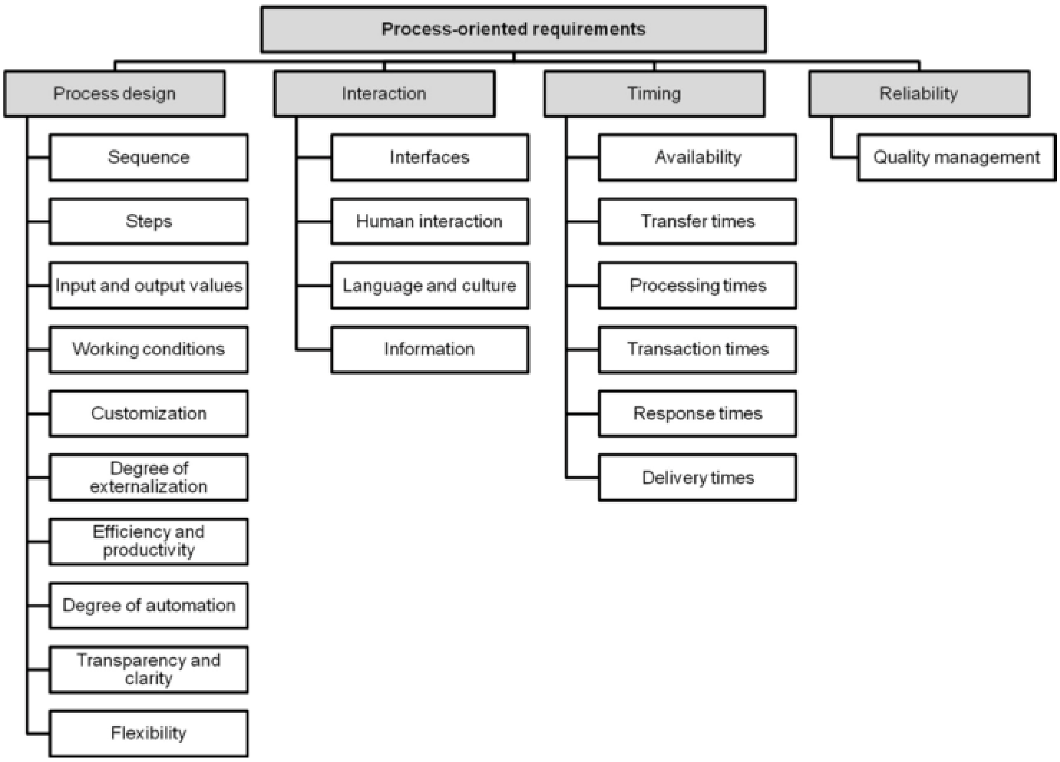

Figure 3-4: Taxonomy of the process-oriented requirements (Berkovich et al., 2014, p. 173)

- Resource-oriented requirements: Summary of necessary resources for the development of a PSS (see Figure 3-5). It includes human resources, facilities, equipment, material, information, capital, and legal requirements (Berkovich et al., 2014, pp. 172–174).

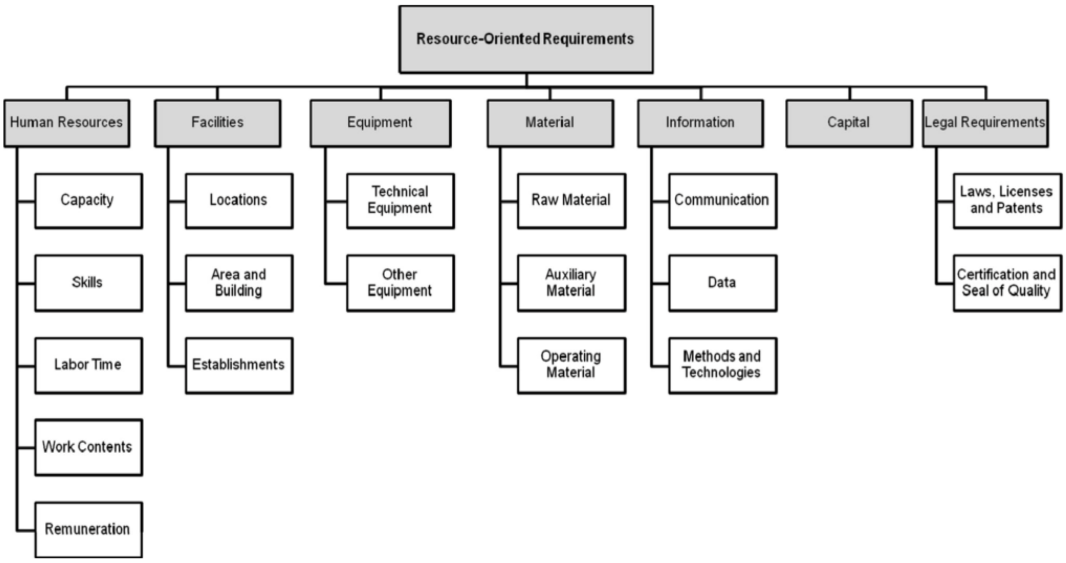

Figure 3-5: Taxonomy of the resource-oriented requirements (Berkovich et al., 2014, p. 173)

A further description of the collection of requirements is presented in chapter 4.2.1. Additionally, their possible classification and connection to the contextual influences affecting the development process of a PSS are explained. The tools available for the prioritization and forecast of the behavior of the requirements are detailed in chapter 3.3.

3.2.2 Product-Service System (PSS)

A Product-Service System combines product and service elements. The product components include mechanics, electrics/electronics, and software (Schenkl et al., 2013, p. 919). There are many other authors dealing with the topic of PSS and some definitions are collected on Table 3-2.

Table 3-2: Product-Service System Definitions

Source	**Definition**
(Baines et al., 2007, p. 1543)	"The concept of a Product-Service System (PSS) is a special case of *servitization*. A PSS can be thought of as a market proposition that extends the traditional functionality of a product by incorporating additional services. Here the emphasis is on the "sale of use" rather than the "sale of product". The customer pays for using an asset, rather than its purchase, and so benefits from a restructuring of the risks, responsabilities, and costs traditionally associated with ownership"
(Bianchi, Evans, Revetria, & Tonelli, 2009, p. 30)	"Product-Service Systems (PSS) are new business strategies moving and extending the product value towards its functional usage and related required services."
(Vezzoli et al., 2014, p. 31)	"An offer model providing an integrated mix of products and services that are together able to fulfill a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions"
(Qu, Yu, Chen, Chu, & Tian, 2016, p. 2)	"The concept of Product-Service System (PSS) was proposed by the United Nations Environment Program (UNEP) in the late 1990s. Its core idea is to provide solutions to customers by integration of "products" and "services", meeting customers' requirements while reducing resource consumption and environmental impact at the same time."

Tukker (2004) classifies PSS into three groups depending on this complex relationship between product and service:

- Product-oriented PSS: This business model concentrates on the traditional sale of customer owned products, which are extended with additional services during the product lifecycle. For the customer, the important element is the product, not the service (e.g. car seller).
- Use-oriented PSS: This business model concentrates on products usually not owned by costumers. Instead, companies offer the availability in order to maximize the utilization of the product. Nevertheless, the product still plays a major role in the business model (e.g. car sharing).
- Result-oriented PSS: This business model concentrates on the desired result, rather than in a specific product. The provider sells capabilities instead of traditional products. Consequently, customers pay for results, without owning the product (e.g. taxi service).

The objective of most companies is shifting from the production of high-quality products to the provision of added-value services to the customer (Aurich, Fuchs, & Jenne, 2005). This is promoted by the low labor costs of production in emerging economies (Neely, 2007). The service embeddedness and customization add value to the products, making it difficult for competitors to copy them and helping to retain customers (Corrêa et al., 2007, p. 445). For this reason, companies have shifted from process and product innovation to *servitization* integrating value-added services to their core products (Lockett et al., 2011, p. 293).

Customers are nowadays in the center of the market. They ask for solutions and not products. Therefore, companies should be able to identify these demands and cover them with their offerings. This strategic shift from products to customers is making companies introduce more often PSS solutions in their portfolio (Vogel-Heuser et al., 2014).

Product-Service Systems allows companies to provide more advanced end-to-end solutions adapted to their customers' needs (Eigner & Stelzer, 2008). Concentrating on the customers' needs and not on the product itself has various advantages like enhancing added-value through customization, readjusting to changing requirements during the lifecycle, planning for multiple generations, which allows reusing and remanufacturing of products, and extending the lifetime of the product with adaptive maintenance (Umeda et al., 2012, p. 689).

Most businesses include tangible products and services in their portfolio. Recently, the service idea is increasing its importance compared to the material product. PSS offers have been more popular so far in Business to Business offers (B2B) (Tischner & Vezzoli, 2009, p. 35). PSS implementation is a complex task because it includes all the relations between the tangible product and the value adding service. PSS aims at adding value rather than reducing the production cost.

However, few studies approach the qualitative and quantitative decision-making strategies for these types of products. A PSS proposal could become a failure when a company does not examine accurately its ability to change or fully comprehends the market dynamics (Bianchi et al., 2009, pp. 30–31). Services and goods are usually delivered together, so research should focus on its combination and not on a pure service or product point of view (Corrêa et al., 2007). It can be derived from the literature that PSS may bring increased economic, environmental and social benefits than traditional products.

The complexity of PSS demands a comprehensive understanding of the system. This information should be acquired on the initial stages of the development process. For this purpose, it is necessary the prediction and analysis of the external influences during the entire life cycle of the future PSS (Hepperle, Orawski, Langer, Mörtl, & Lindemann, 2011).

3.3 Product-Service System Design Methodologies

Existing methodologies proposed for the Product-Service Systems design are reviewed in this chapter. Only methodologies proposed in the field of PSS have been examined. After a systematic literature review, six perspectives were identified: complexity management, Service Engineering (SE), innovation, product lifecycle, and product upgrading.

Mörtl et al. (2014, p. 91) describe a systematic analysis procedure for the planning phase of future PSS. The starting point is the early phase of the innovation process. The presented methodology consists of several combined matrixes. Their utilization helps to deal with complex technical systems.

However, it needs to verify the compatibility of different partial solutions into the total solution by performing compatibility analysis. In the matrix-based approach, the inconsistent solution elements are identified and excluded in order to choose the best combination possible. This procedure allows the compatibility of the overall concept while guaranteeing decision-making in all individual aspect (Mörtl et al., 2014, p. 91).

Service Engineering, which deals with the design and development of product-services, is becoming more significant. SE considers both user and producer perspectives (Pezzotta et al., 2013, p. 2). Pezzotta et al. (2013) adopt the model of Service Engineering, which usually addresses traditional engineering solutions, to the PSS configurations. They propose a Service Engineering framework that enables the comparison of several PSS arrangements. The framework is based on five phases: idea, value, process, simulation, monitoring and represented in Figure 3-6 (Pezzotta et al., 2013, p. 5).

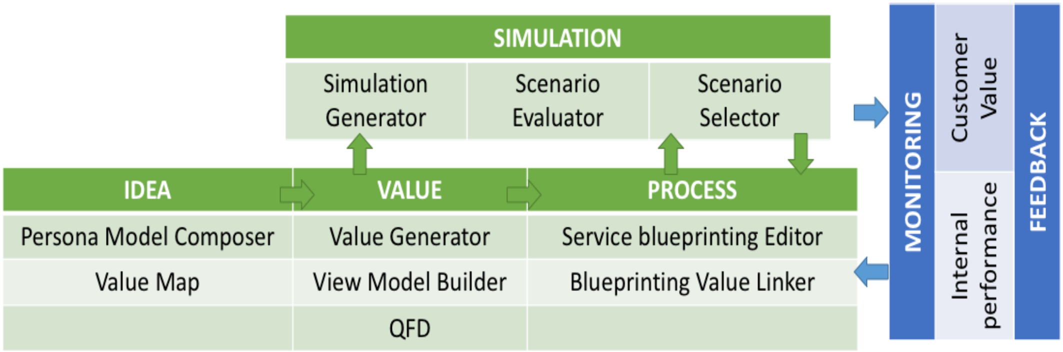

Figure 3-6: The framework for Product-service engineering, modified (Pezzotta et al., 2013, p. 5)

Some approaches focus on the innovation process of PSS since it is an innovative concept with which many companies are not familiar. Lindemann (2007) developed a model that consists of seven phases (demand, analysis, idea generation, design, production, introduction, and utilization) (see Figure 3-7).

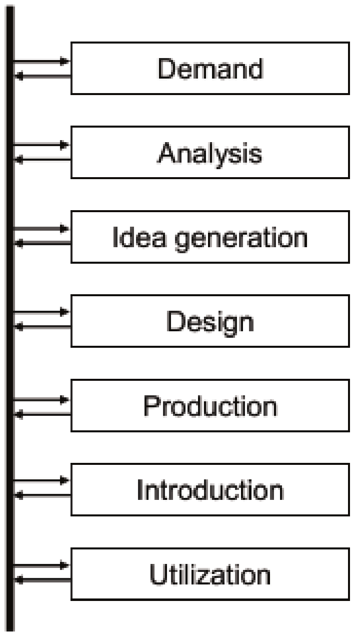

Figure 3-7: Model of the generic innovation process and the understanding of cycles (Lindemann, 2007)

In addition, Langer & Lindemann (2009) focus on the challenges that arise during the innovation process, differentiating elements from the internal process (research and development, production, logistics, finance, and service) and company's externalities (available production technologies, customer requirements, personnel, competitive environment, society or product life cycles).

The relationship between manufacturers and customers change in the case of PSS from that of traditional products. This dependence remains beyond the purchase because the manufacturer provides a service that lasts as long as the life of the PSS (Lockett et al., 2011, pp. 293–294). Aurich, Fuchs, & Wagenknecht (2006) remark the differentiation of the design process of PSS regarding its life cycle perspective:

- Manufacturers: product design, product manufacturing, product servicing and product remanufacturing.
- Customers: product purchasing (e.g. sales counseling, and commissioning), product usage (e.g. maintenance, retrofitting, and teleservice) and product disposal (e.g. take-back, and refurbishing).

Likewise, the model of Hepperle, Orawski, Langer, Mörtl, & Lindemann (2011) covers all phases of the PSS lifecycle: development, production, distribution, utilization, and recycling (see Figure 3-8). The examination of these interactions among phases during the design of a PSS may help the early detection of probable conflicts and the prevention of costs, which increase exponentially with the later identification through the lifecycle.

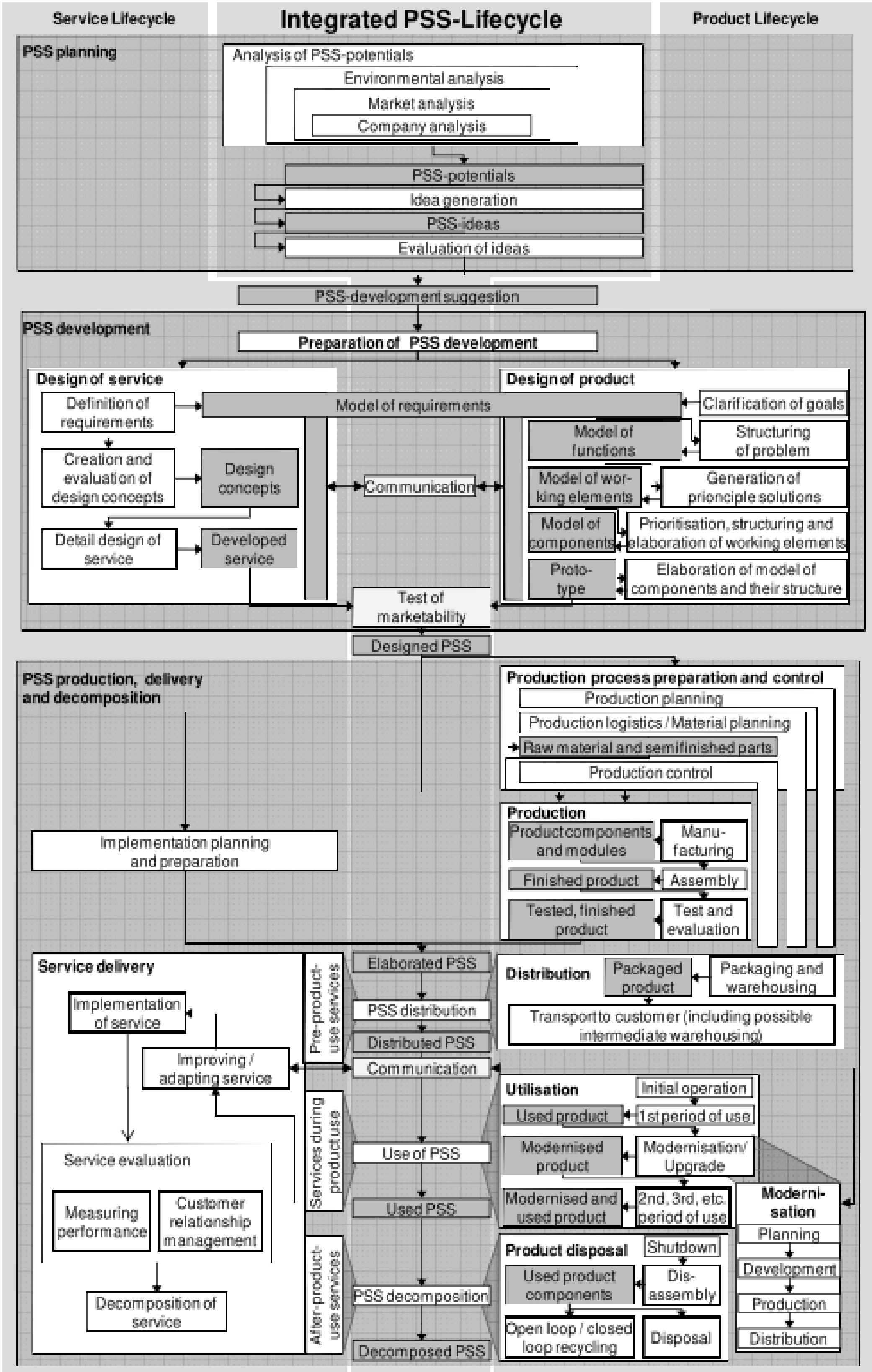

Figure 3-8: Integrated PSS lifecycle (Hepperle et al., 2011, p. 341)

Life cycle planning consists of understanding the relationship between the life cycle strategy and the interaction of external factors with it. Providing general methodologies that consider the time factor and formalize this relationship is one of the central areas of lifecycle planning study (Umeda et al., 2012, p. 684). According to Umeda et al. (2012, p. 682) the activities that define a product lifecycle are the planning, the design, and the implementation of a product. These actions include processes like procurement, manufacturing, use, and disposal or recycle. The arrows at the center of Figure 3-9 represent one product lifecycle (it begins with procurement and ends with the end of life) (Umeda et al., 2012, p. 682). According to this approach, the life cycle development consists of three steps:

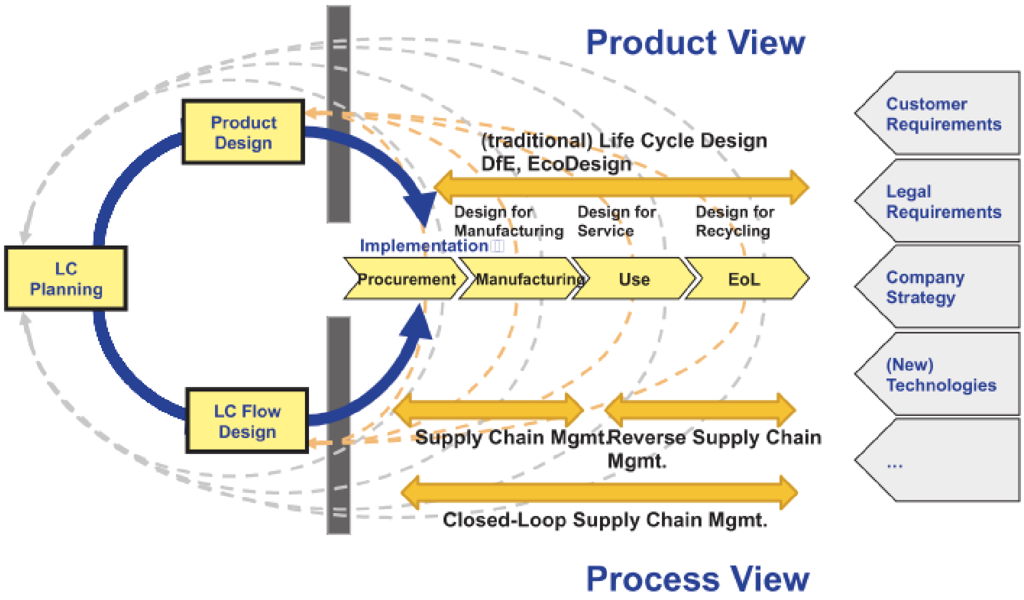

Figure 3-9: Life cycle development (Umeda et al., 2012, p. 682)

1. Lifecycle planning: The development team represent a life cycle plan containing the strategies of the product (Umeda et al., 2012, p. 682).
2. Product and lifecycle flow design: To achieve the previously designed plan, the team adapts the plan to the life cycle perspective. By doing this, the plan is effective through the entire life cycle (Umeda et al., 2012, p. 682).
3. Implementation of the designed product lifecycle: The plan is implemented, and the product developed. This is also called life cycle management (Umeda et al., 2012, p. 682).

The product lifecycle approach also includes the evaluation of the effects of the planned strategy under various external factors (see Figure 3-10). The evaluation of the lifecycle approach should be made from different perspectives because of the existence of influence factors on different areas such as politics and legislation, environment, costumer, product and technology, and organizational (Umeda et al., 2012, p. 692). Furthermore, the evaluation should not focus only on a particular product, but on multiple ones or multiple generations of the same product (Umeda et al., 2012, p. 692). These two ideas about external factors and multigeneration aspects will be further discussed in this thesis.

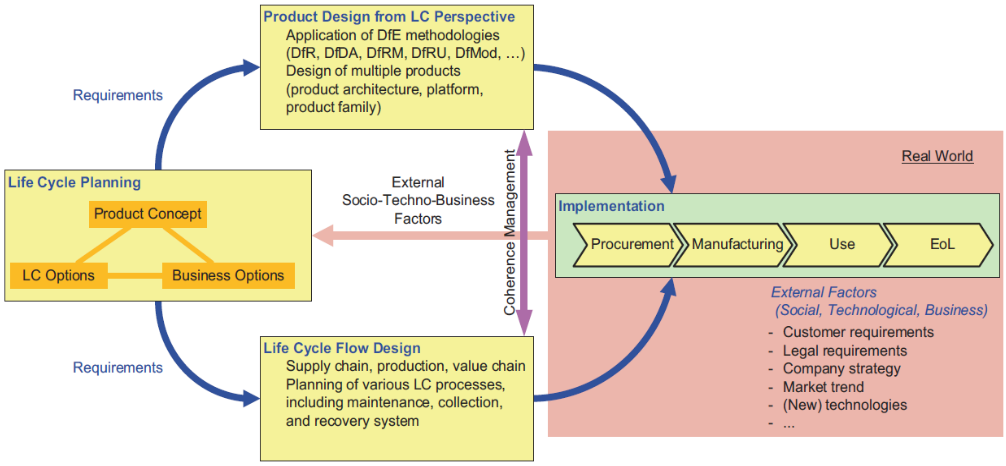

Fig. 2. Position of life cycle planning in life cycle development.

Figure 3-10: Life cycle planning in life cycle development (Umeda et al., 2012, p. 683)

Cycle management identifies and analyzes internal and external cycles that affect the PSS development process (Vogel-Heuser et al., 2014, p. 90). The available theoretical and empirical approaches do not cover entirely the topic of the cycles within the PSS. A cycle is a recurring (temporal or structural) pattern which may be divided into phases. It is characterized by repetition, phases, duration, trigger and effects, where triggers are the reason of the repetition of a phase and result from a deviation of the actual state from the nominal state of an object. This repetition requires a specific time and causes individual effects, which may lead to yet another cycle (Schenkl et al., 2013, p. 918).

Products are frequently developed in generations. This approach enables companies to add new requirements arising from customer's needs to existing products. Nowadays development projects are frequently motivated by existing products. There is usually a reference product that gives the basic structure for the analysis of several generations. The decisions influencing it are quite relevant and should be made in an early planning phase (Weidmann, Stenger, & Mörtl, 2018, p. 1).

Incorporating probable requirements into product design benefits directly the project cost through different life-cycle phases, by reducing it. Through the initial phases of product design, several concepts of the same product coexist. “This complexity is further increased by considering the multigenerational aspect. An optimized design strategy for a single generation may not be the best option from multi-generations” (Tyagi, Cai, & Yang, 2015, p. 698). The planning of a succeeding generation usually starts while the previous one is still in use. Hence, connections between generations are typically parallel instead of sequential (Tyagi et al., 2015, p. 698).

The iPeM (integrated Product engineering Model in context of Product Generation Engineering) is an approach that connects process management and engineering design (Albers & Meboldt, 2007). Albers et al., (2016) adapt the extension of the model and add four different layers: product generations, strategy, production, and validation system. Figure 3-11 is the graphical representation of the iPeM.

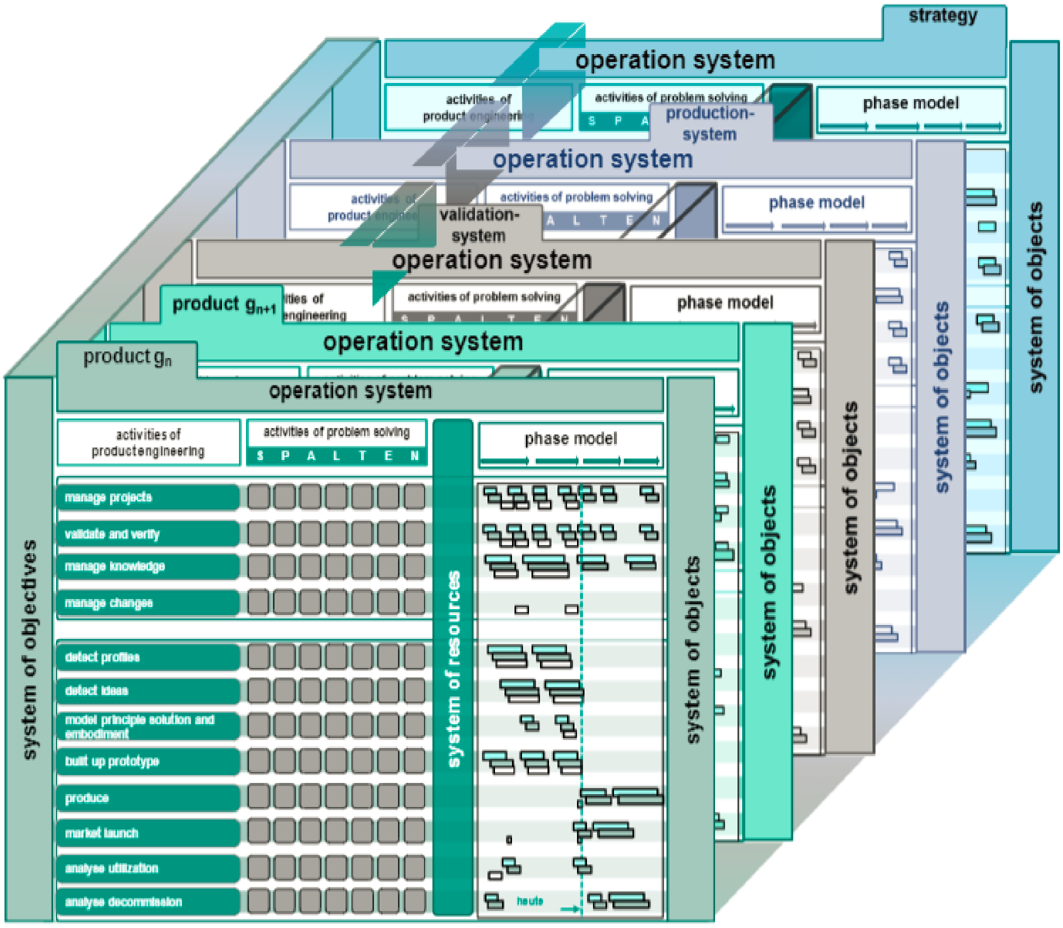

Figure 3-11: Graphical representation of iPeM (Albers et al., 2016, p. 5)

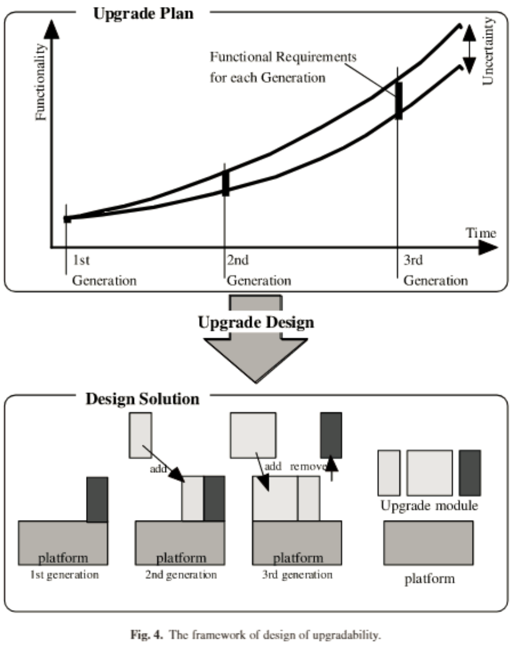

Figure 3-12: Framework of upgradability design (Umeda, Kondoh, Shimomura, & Tomiyama, 2005, p. 165)

Designers should manage long-term plans that facilitate the introduction of upgrades among various generations. Long-term planning anticipates future trends influencing the product, thus, involves uncertainty. The more accurate the forecast is, the better the plan will work. Different aspects such as technological, customers' needs, competitors and companies' policy trends should be examined for the elaboration of the plan. This method should also include the requirements of the product as well as the go-to-market timing of newer generations (Umeda et al., 2005, p. 165).

Umeda et al. (2005, p. 165) developed a methodology for multiple generations that separates the products into a fixed part called "platform" that remains constant within all generations and "upgradable modules" that consider the uncertainty inherent to future generations (see Figure 3-12).

Hepperle et al. (2011) present an approach to reflect the temporal dimensions of the lifecycle phases in particular planning projects. This procedure is not restricted to single products but takes into account several generations. Figure 3-13 shows the gap separating product generations.

The phase of development and selling to customers leads the planning range for the following launch. The more cycles that are taken into account, the longer the planning horizon becomes. In strategic planning, there are three distinctive planning horizons: short-term (around one year); medium-term (between one and five years); long-term (beyond five years) (Bea, Friedli, & Schweitzer, 2005). The selection of a planning horizon relies on the nature of the product and its lifecycle extension, but also on the desired forecast of requirements for further generations (Hepperle et al., 2011, p. 340).

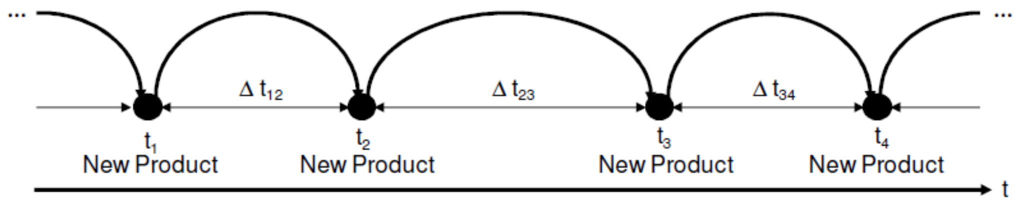

Figure 3-13: Cycle of launching new products (Hepperle et al., 2010, p. 1106)

The product roadmap should acknowledge multiple product generations. It is of particular interest the duration between the launch of two consecutive generations. External circumstances often determine this gap. However, companies should foresee it in order to innovate not only depending on external drivers. The development stages of a second generation may overlap with other lifecycle phases from the previous one. For this reason, it is critical to pick the right moment to begin the development of the following product generation (Hepperle et al., 2011, p. 343).

Additionally, Hepperle (2013) explains the dimensions to be examined for lifecycle-phase product planning (see Figure 3-14). Through some examples, the main elements are named: market entry point, distribution period, and also re-use and recycling stages. However, these phases overlap each other. For example, recycling starts with the beginning of sales if one of the products have a shorter life cycle than anticipated due to contingencies or unforeseen events (Hepperle, 2013, p. 109).

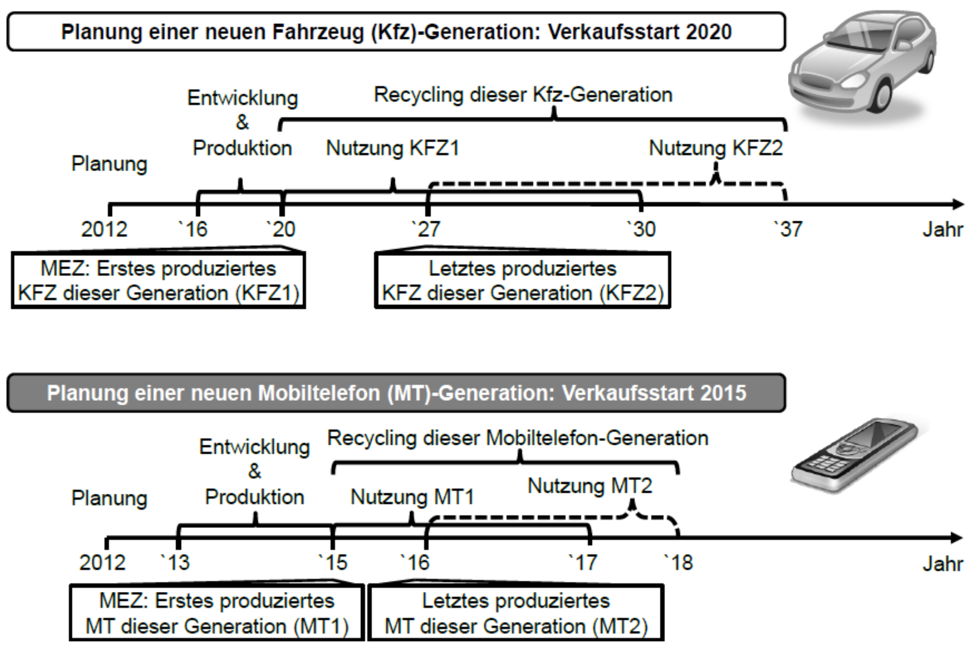

Figure 3-14: Time horizons of different products (Hepperle, 2013, p. 116)

Langer, Herberg, Körber, & Lindemann (2010) include the integration of the process and context perspectives on cycles in a mutual model represented on Table 3-3.

Table 3-3: Exemplary cycles from the development process, modified (Langer et al., 2010, p. 1798)

	Decomposition / Distance	Examples of cyclic aspects
Process layers	Strategic process level	Reoccurring development projects, patterns in roadmaps, etc.
	Project level	Milestones, procedural models, project phases, etc.
	Operational level	Reoccurring decision points, iterations and changes, etc.
	Action level	Reoccurring elementary process steps, etc.
Context layers	Environment	Demographic alterations, political changes, etc.
	Market	Evolving new technologies, market dynamics, etc.
	Company interfaces	Purchase activities, sales and marketing activities, etc.
	Company	Changes in leadership, changes of organizational structures, etc.
	Development Process	Withdrawals of co-workers, changes of team structures

3.4 Contextual factors of Product-Service Systems

The central subject of this study is context factors and their impact on the development of future PSS. "These context factors often have a cyclic character, meaning they are (temporally or structurally) reoccurring" (Grüneisen, Stahl, Kasperek, Maurer, & Lohmann, 2015, p. 120). Contextual factors interact with the product life cycle in a dynamic way, which means, they are not static in time. They change throughout the development process of the product. For this reason, a crucial step of life cycle planning is to define the link between the life cycle strategy and the contextual factors (Langer & Lindemann, 2009, p. 539). Development processes come along with circumstances that affect them. These influences, as well as the activities of the development plan, can vary and evolve over time (cycles) (Langer & Lindemann, 2009, p. 547).

The collection of influence factors in all fields is not only the responsibility of the designer. It is essential to include in this process all areas of the development process as well as external stakeholders whose decisions also affect the final output (Hepperle, 2013). Historically, marketing departments have handled the research on influencing factors, concentrating entirely on the reception of new products among customers. Consequently, the existing approaches highlight the utilization phases and usually not consider other lifecycle phases such as production or recycling despite their impact on coming products (Hepperle et al., 2011, p. 339).

Existing approaches for the identification and the classification of contextual factors of PSS are reviewed in this chapter. The requirements to consider the approaches into the analysis is the following:

- The classification should be focused on PSS.
- The classification should be detailed.
- The sources should be available.
- The approaches should be published in peer-reviewed journals.

Considering these criteria, five approaches were selected for study. The restriction helps to avoid loss of focus and prevents from overcharging the study. The approaches selected are sufficiently detailed and highly referred to within the Product-Service Systems community.

Table 3-4 details the approaches chosen resuming their approach, the references for each of them and the suggested classification of contextual factors proposal. Other methods that did not fulfill all criteria but that show interesting concepts about contextual factors are cited at the end of this chapter. This is the case of those sources that do not focus on Product-Service Systems, and they present a classification for influence factors in other domains. The results of this chapter serve as a foundation for the future development of an original classification of contextual factors in chapter 3.2.2.

The selected approaches include the influence factors of successful transitions from traditional products to Product-Service Systems, the influence factors on the development processes and their cyclical behavior, the factors affecting the innovation processes, the factors influencing the business model of a company and its degree of customization, and a future-oriented perspective of contextual factors.

Table 3-4: Contextual Factors Literature Review

APPROACH	SOURCE	CLASSIFICATION	CONTEXTUAL FACTORS
Transitions towards Product-Service System	(Gebauer & Friedli, 2005)		Risk aversion, economic potential of services, fundamental attribution error, setting up structures and processes, first and second order structural change, employee perception of transition, adequate objectives
	(Bianchi et al., 2009, p. 30)	External	Legislation, competition, consumerism, quality of life
		Internal	Innovation
Cycles in development processes	(Langer & Lindemann, 2009, p. 544)	Environment	Society: culture, demography, economy, policy, legislation, norms, ecology, random
			Technological development: research / academia, industry (external), industry (internal)
		Market	Purchases: funding, product components, manufacturing technology, services, human resources, energy, raw materials, knowledge / information
			Sales: stakeholder demographics, stakeholder requirements, market position
		Company interfaces	Purchasing, market analysis & requirements engineering, stakeholder integration, sales & marketing, customer services
Innovation	(Schenkl et al., 2013)	Internal context factors	Customer demand for innovations
		External context factors	Challenging laws and regulations, incremental and radical innovations of product and production technologies
	(Vogel-Heuser et al., 2014)	Innovation	Strategy, knowledge, technology
		Boundary conditions	Politics, resources, society
Business model	(Joha & Janssen, 2014, p. 54)		Path dependency, legal/regulatory driver, customer orientation, target segment, strategic importance, ICT/business orientation, IT governance structure, change strategy, degree of outsourcing, integration potential, economic rationale, business value

Gebauer & Friedli (2005) investigate the behavioral process during the transition from product manufacturer to service provider focusing on German and Swiss industries. They rely on case studies as the principal tool for their theory development. The authors found seven key behavioral processes: risk aversion, economic potential of services, fundamental attribution error, setting up structures and processes, first and second order structural change, employee perceptions of transitions, and adequate objectives (Gebauer & Friedli, 2005, pp. 72–74).

Bianchi et al. (2009) also focus on the transitions towards Product-Service Systems. The identification of primary influencing factors and its interpretation over a certain time horizon is fundamental for determining whether to adopt a PSS model. The classification involves a qualitative and quantitative approach (Bianchi et al., 2009, p. 31). They consider seven PSS value propositions (Bianchi et al., 2009, pp. 31–32):

- Government intervention.
- Economical convenience.
- Legislation.
- Drivers for PSS adoption.
- Sustainability
- Materials.
- Product portfolio.

The evolution of innovative products is affected by various external and internal parameters with a dynamic temporal performance. Langer & Lindemann (2009) developed a model to solve this issue in the classification of contextual factors (see Figure 3-15).

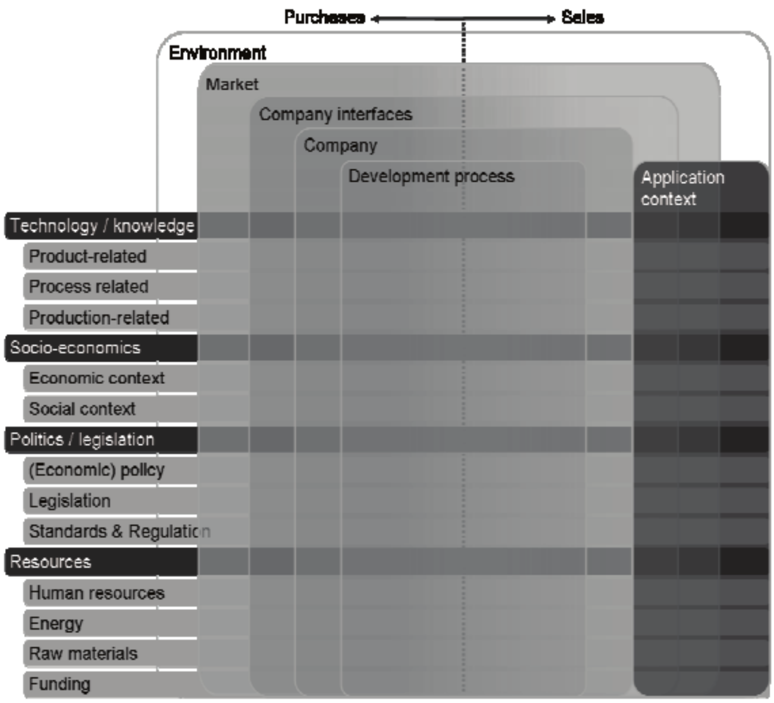

Figure 3-15: Model for classification of external context factors (Langer & Lindemann, 2009, p. 546)

The framework includes the monitoring of cycles in the development context. The context classification consists of five elements (environment, market, company interfaces, company, and development process). To facilitate the allocation of factors a distinction between purchases and sales is introduced (Langer & Lindemann, 2009, p. 546).

Regarding innovation, two sources were found. Nevertheless, the classification of the influence factors differs from one to the other. On the one hand, Schenkl et al. (2013) distinguish between internal and external factors. On the other hand, Vogel-Heuser et al. (2014) focus on the boundary conditions of innovation. Companies have to handle internal and external context factors on innovation processes (Schenkl et al., 2013, p. 918). Schenkl et al., (2013) present an overview of cycle management showing relevant cycles for the innovation process (see Table 3-5) as a result of expert workshops conducted in the disciplines of mechanical engineering, computer science, social science, and management science (Schenkl et al., 2013, pp. 921–922).

Table 3-5: Relevant cycles within the innovation process of PSS, modified (Schenkl et al., 2013, p. 922)

LEVEL	**CONSIDERED CYCLE**
Environment	Changes within the environment
Market	Changes within the market
	Cycles of customer demand
	Customer life cycle
Processes	Cycles of team processes
	Cyclic changes of requirements
	Cyclic changes of requirement usage
	Iterations within the development process
	Cycles of innovation projects
	Cycles of production planning
	Cycles of customer integration
Projects	Cycles of project portfolio
	Cycles of product upgrades
PSS-/ Technology-life-cycle	Cycles of technology maturity
	Cycles of technology changes
	PSS life-cycle

Vogel-Heuser et al. (2014) also approach the influence factors from a cycle management perspective. However, they focus mainly on the boundary conditions for the innovation process.

Joha & Janssen (2014) identified twelve different factors that influence the shape of shared services business models. These factors include the path dependency, legal and regulatory driver, customer orientation, target segment, strategic importance, ICT/business orientation, IT governance structure, change strategy, outsourcing degree, integration potential, economy, and business value (Joha & Janssen, 2014, p. 62).

The only approach found with a future-oriented vision is the one of Hepperle et al. (2010). Although not focused on Product-Service Systems, Hepperle et al. (2010) develop a procedure to assign factors to categories. The focus is on the launching time of new products, so in their case, two groups are identified: factors which lead to an unintentional delay of the market launch of new products, and factors which lead to an intentional delay of an innovative product (see Figure 3-16).

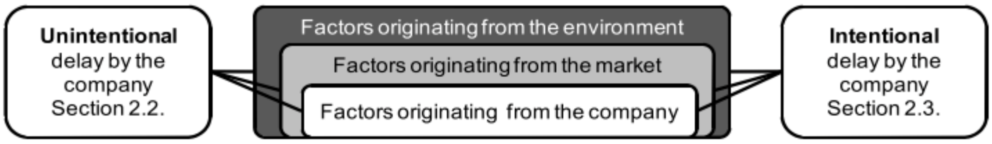

Figure 3-16: Categories of factors influencing the time of launching innovations (Hepperle et al., 2010, p. 1102)

Besides classifying the factors into categories, it includes more dimensions with the temporal aspect in the model (see Figure 3-17). Their framework includes all phases of the lifecycle and takes into account the temporal dimensions of the factors: how they change over time (changing behavior) and when does the factor impact (impact behavior) (Hepperle et al., 2010, p. 1106).

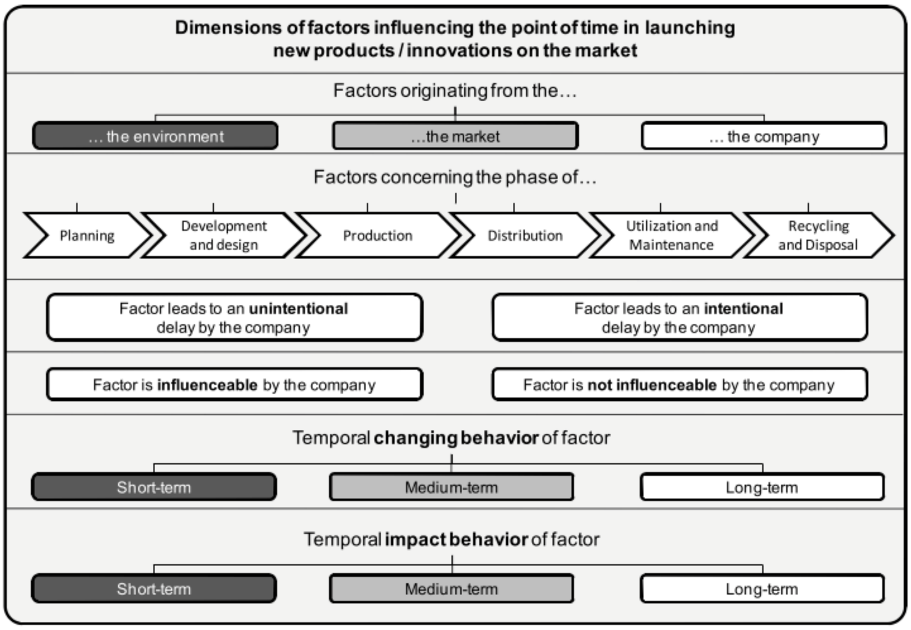

Figure 3-17: Framework for classification of factors (Hepperle et al., 2010, p. 1106)

The following are the conclusions reached after analyzing the different approaches exposed above:

- Even though different influence factors' approaches exist, with different classifications, some of the factors are present in the majority of the classifications: legislation, sustainability, innovation, and technology.
- Most approaches are developed or only applicable in specific situations. There is a lack of literature covering the influence of contextual factors without case specific differentiation.
- The majority of the approaches include a single generation perspective. In this review, no studies concerning the influence of factors in a multi-generational aspect could be found. Only one approach, without focusing on PSS, develops a classification that takes into account the future-oriented vision.

3.5 Research opportunity

After analyzing the collected information, the state of the art ends with the identification of a research gap. It points out the necessity to develop a general procedure that deals with the planning of PSS and the effect of the contextual factors in multiple generations. For organizations, it is a significant challenge to identify the influences affecting their business. Furthermore, it is a difficult task to set the boundaries of these influences and understand interdependencies between them. Internal and external influences affect the core products of the companies and they might conflict with organizational objectives. For this reason, their identification is vital for the firms' strategy (McQuater et al., 1998).

The thesis has three principal objectives that were presented in chapter 1.3. The first one deals with the contextual factors affecting PSS, the second one with the development of a procedure that supports designers in their planning of future PSS, and the third one points out the need of a connection between the influences and the PSS. The research questions are taken as the initial point for the research.

Table 3-6 presents the matrix that summarizes and categorizes the literature review conducted in this work. The listed sources are approaches dealing with one or more of the presented research questions. The structure of the literature review matrix is simple and facilitates the identification of relevant authors. The first column contains the reviewed sources in APA style. The first row lists the fundamental concepts derived from the research questions. Whenever a reference covers a discussion of the idea, a tick is marked in the matrix. Consequently, this method graphically shows the gaps found in the literature.

Table 3-6: Matrix Method of Literature Review

SOURCE	CONTEXTUAL FACTORS	DESIGN METHODOLOGY	PRODUCT-SERVICE SYSTEMS	REQUIREMENTS	PRODUCT GENERATIONS	PRIORITIZATION	FORECASTING
(Albers et al., 2016)		X	X		X		
(Aurich et al., 2006)		X	X				
(Bianchi et al., 2009)	X		X	X			
(Gebauer & Friedli, 2005)	X		X				
(Hepperle et al., 2010, 2011)	X	X			X		
(Joha & Janssen, 2014)	X		X	X			
(Langer et al., 2010)	X	X			X		
(Langer & Lindemann, 2009)	X	X	X		X		X
(Lindemann, 2007, 2009)		X	X				X
(Lockett et al., 2011)		X	X				
(Mörtl et al., 2014)		X	X				
(Pezzotta et al., 2013)		X	X				
(Schenkl et al., 2013)	X	X	X		X		X
(Tyagi et al., 2015)		X	X		X		
(Umeda et al., 2012, 2005)		X	X		X		
(Vogel-Heuser et al., 2014)		X	X	X	X		
(Weidmann et al., 2018)	X	X	X	X	X	X	X

This strategy facilitates the comparison of the references and helps to identify the research gap on the topic, which will be the focus of this thesis.

- Contextual factors: gathering and classifications of contextual factors in the development of a product.
- Design methodologies: tools and methodologies that support the development of new products.
- Product-Service System: sources with a focus on Product Service Systems.
- Requirements: gathering and classifications of requirements of a product.
- Product generations: reference systems, concept of product generations.
- Prioritization: tools and approaches about prioritization techniques.
- Forecasting: tools and approaches about forecasting techniques.

The listed sources present concrete design methodologies for Product-Service Systems. All of them are described in chapter 3.3. Most of them describe defined products or services for different industries. Those approaches do not provide a general procedure valid for any PSS. The approaches are useful for a first overview about planning future PSS.

The next important aspect to be covered is the contextual factors. All approaches covering this topic are presented in chapter 3.4. As it occurred with the design methodology aspect, most of them are centered in a concrete aspect of the PSS and there are no general approaches. For this reason, to serve as a valuable checklist for PSS-designers in all industries, the list of factors affecting PSS will be enlarged in chapter 4.2.2.

The literature research has proved the existence of many studies about PSS and their classification possibilities. Nevertheless, only a few include the entire design process concept and the influence of contextual factors. Moreover, there are no studies that cover these points with a future-oriented perspective. Only one source (Weidmann et al., 2018) meets all the elements to be considered in this thesis. However, most of them assist in the development of a new methodology by providing information about the different sections. At last, the reflection of various planning horizons is rarely approached and becomes an essential issue of this study.

It should be noted that there is not much literature available about contextual factors on PSS. Moreover, most of the approaches only present an overview or a list of different influences so one of the important challenges is the conceptual gap between the contextual factors and the design methodologies of the future PSS. Only Langer & Lindemann (2009), Schenkl et al. (2013), and Weidmann et al. (2018) present an approach connecting both aspects.

The following points summarize the issues that need to be addressed in the procedure developed in chapter 4.

- A procedure for planning PSS that integrates the design methodology and the contextual factors through the requirements of the solution.
- Identification of the requirements involved in the PSS to serve as a support function for the designer.
- Identification of the contextual factors involved in the PSS to serve as a support function for the designer.
- Consideration of the multigeneration aspects and future-oriented vision.
- Identification and analysis of prioritization tools for the selection of key aspects.
- Identification and analysis of forecasting tools for the prediction of future aspect behavior.

4 Systematic procedure for the connection of future contextual factors with Product-Service Systems

The developed procedure will be displayed in this chapter. This approach is intended to work as a systematic support for designers planning Product-Service Systems. In the beginning, the description of the requirements expected to be fulfilled by the procedure will be discussed. After that, an overview is provided, and the individual modules are explained in detail in the following chapters.

In this part, following the idea raised by RQ3, theoretical approaches and methodological tools are suggested with the purpose of assisting the planning of future PSS. These approaches combine general guidance, like the determination of a comprehensive procedure, and some specific activities such as the creation of a checklist containing the key influencing factors.

This chapter presents in detail the functioning of the procedure. It supports companies implementing PSS, that are based on technical products, and add services that improve the customer's benefit of the business proposition (Schmidt, Jaugstetter, Malaschewski, & Mörtl, 2015, p. 1).

4.1 Elements and structure of the procedure

The following points summarize the elements that are addressed in the procedure. Elements one to seven are already described on the literature review matrix presented in chapter 3.5 and elements eight and nine are added during the development of the procedure and presented in this section.

1. Requirements: reference Product-Service System's requirements gathering and classification tools.
2. PSS: the procedure focuses on PSS planning. It is not a procedure for traditional products.
3. Planning approach: the procedure is aimed to support the development of new products.
4. Product generation: the procedure is based on reference systems that serve as a basis for future product generations.
5. Contextual factors: the procedure serves as a tool for gathering and classifying the contextual factors in the development of a future Product-Service System.
6. Prioritization: the procedure contains tools and approaches focusing on prioritization techniques.
7. Forecasting: the procedure contains tools and approaches focusing on forecasting techniques.
8. Traceability: each step of the analysis should be traceable. To achieve this requirement, all defined elements of the model should be defined by predecessor and successor relationships.

9. Interdependencies: the interdependencies between the requirements and the contextual factors should be highlighted.

The procedure is shown in Figure 4-1 and aims to specify the steps to follow by PSS designers involved in developing a PSS based on a reference product. It should help to the conception of adaptable PSS in a systematic way.

The proceeding consists of three steps: the first step is to identify the requirements and contextual factors of existing reference products. The identified elements are then grouped and selected according to their relevance and their future behavior, which are simultaneously forecasted. Redundant factors are eliminated in this step, in an effort to simplify the classification. Finally, the key forecasted requirements should be implemented on the PSS in a more detailed level.

The procedure segregates requirements and contextual factors, reflected in two different rows, and it serves as a design for the connection of the two aspects. It defines how the requirements can be classified, prioritized and forecasted across the various design phases taking into account their context at all times in a chronological order. Initially, an identification phase takes place, followed by a simultaneous prioritization and forecasting of the requirements phase. Finally, the implementation and the evaluation phase of the procedure take place (see Table 4-1).

Table 4-1: Steps in the model

STEPS IN THE MODEL	SUGGESTED TOOLS	CHAPTER
1. IDENTIFICATION		Chapter 3.2
a. Existing reference system requirements identification and analysis	Creativity techniques that help building a requirements' list for analyzing existing reference system	Chapter 3.2.1
b. Existing reference system contextual factors identification and analysis	PEST analysis that helps building a checklist for analyzing existing reference system	Chapter 3.2.2
2. PRIORITIZATON AND FORECAST		Chapter 3.3
a. Adjustment to future PSS idea	SWOT analysis, customers and experts' interviews, value proposition canvas, pairwise comparison, clustering,	Chapter 3.3.1
b. Selected aspects forecast	Quantitative and qualitative forecasting methods with different time horizons: prognosis, scenario planning, trends, benchmarking	Chapter 3.3.2
c. Essential aspects selection	2x2 SCRUM Matrix, weighting, influence matrix	Chapter 3.3.3
3. IMPLEMENTATION AND EVALUATION Tools: Service blueprint, wireframe		Chapter 3.4

In the first stage (1) PSS information is collected regarding existing reference systems of PSS. Essential aspects are the product requirements (1a) and the external factors influencing them (1b).

The second stage (2) includes four steps in which significant information is selected and organized along with the possible forecasting methods. The first step is to adjust the collected information that comes from the reference product to the actual PSS (2a). The next two steps (2b, 2c) are performed in an indeterminate order and in an iterative way. The forecasting proceeding could be executed for different time horizons. The now forecasted influences are connected with the PSS's requirements and presented as a list of specifications for PSS implementation. The last step presents a collection of the fundamental forecasted requirements (2d).

Based on these results, the third step would include the implementation (3a) and the evaluation of the concepts and testing if possible (3b). However, the contribution of this thesis is mainly to give a possible solution for the two initial phases of the presented procedure.

The stakeholders' requirements and contextual factors obtained from the previous generation constitute the starting point of the procedure. The structured procedure aims to improve and facilitate the planning of future PSS based on current reference products from preceding generations. The challenging point is the connection between the product and its future circumstances. The model takes into account different levels of concretization and different time planning horizons always in a chronological order. There are two principal aspects affecting the planning of a PSS: the requirements of the solution and the contextual factors influencing them.

The examination of the requirements and contextual factors is of high value for planners. For instance, they might not know which technologies will be adopted in the future if the production of the company is outsourced. Nevertheless, when introducing the stakeholders in the analysis, the planner can include the technology suppliers' know-how into the planning of the PSS (Hepperle, 2013).

Diverse areas of the company should be considered for developing the procedure. It is helpful to contrast different planning reports coming from all departments, connect them and elaborate a consistent, future-oriented plan (Weidmann et al., 2018). The availability of integrated systems that support the planning of future PSS in early phases is a huge advantage for organizations. The appropriate coordination of requirements and components is very helpful in the innovation process of a company (Hepperle et al., 2011, p. 338).

The selection of a planning horizon is essential for the creation of the procedure. As discussed in the state of the art, many authors approach the topic of development processes in PSS, though usually concentrating on a single product generation. In this thesis, long-term planning for future product generations is proposed. Decisions made for the current generation, will affect the future generation lifecycle and outcome.

This procedure is intended to allow companies to design PSS in an effective manner, predicting future changes. The scheme comprehensively describes the necessary steps and explains the recommended methods on the initial stage of the planning process. The presented guide may be taken as a manual for planners when designing new Product-Service Systems. Furthermore, the suggested tools for the completion of the different steps of the procedure will be analyzed.

Existing working methods to collect, prioritize and forecast elements are presented and analyzed in this thesis. As Lindemann (2009) explains, models are used within the development process to complete individual steps in an efficient way. Methods should be applicable in the user's daily work. In order to support the designer on the use of these tools, the steps to follow in every tool are also detailed.

The basic structure of the procedure is shown in Figure 4-1, and then will be explained in detail in the next chapters. The guide presents a simple structure with three columns in dark blue representing the main phases of the procedure (identification, prioritization and forecast, and PSS implementation and evaluation). There are two rows in light blue that represent the distinction between requirements and contextual factors, and each individual step is described in a box, which is connected to the others using arrows. By following the arrows, the user of the procedure can follow it in the correct order.

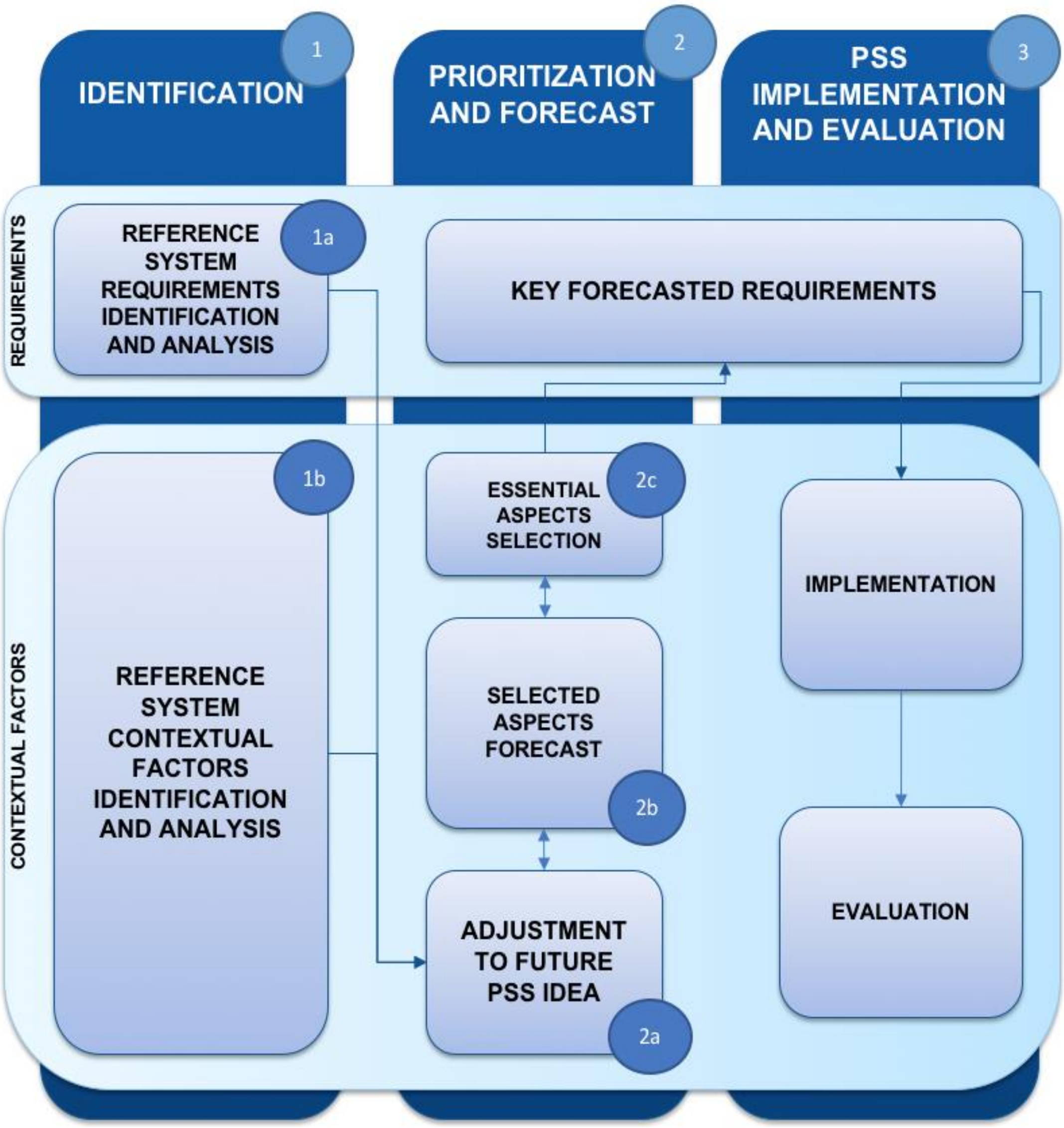

Figure 4-1: Systematic procedure for the connection of future contextual factors and PSS

4.2 Identification

This chapter is the first step into the procedure for the analysis of contextual factors in PSS. It aims to construct a classification scheme that serves as a checklist for PSS-designers. This allows designers to identify and selects the most relevant requirements of the PSS. In order to handle the big amount of information provided by the reference product, feature clusters are recommended. They may include two levels: requirements and external influences.

As this thesis presents a general procedure for any type of PSS, the first step is to identify a high number of requirements as well as contextual factors to facilitate the classification model and cover a broad spectrum of PSS. For this, a literature review was conducted, covering papers, which deal with PSS from different perspectives to identify requirements and contextual factors.

4.2.1 Existing reference system requirements identification and analysis

The market trend is currently shifting from a product-oriented to a customer-oriented focus, locating customer requirements in the center of the development project objective. The customer needs are continually changing increasing the prediction and acquisition of customer requirements difficulty. Different procedures can be relied on, this chapter summarizes how the requirements can be systematically gathered and documented for product development planning. Before beginning with the planning of a new PSS, it is convenient to deal with the collection of requirements that arise from every division of a company, and their analysis is helpful for the success of product development (Lindemann, 2009, p. 94).

For the identification of the requirements necessary for the development of the new PSS, creativity techniques like brainstorming can be used. Nevertheless, it is also useful to analyze the existing reference system requirements, which are usually documented in requirements' lists. Once new as well as existing requirements are collected, they should be organized in a new requirements list.

In the planning phase of a new product, creativity techniques can be applied in order to gather information. Through unrestricted thinking, the participants could determine new requirements of the future product. Even though these methods do not involve a complete definition of the requirements, they are very helpful to gather a large amount of them (Pohl & Rupp, 2010, p. 35).

One of the most used creativity techniques is brainstorming, in which a group of participants collect ideas and options for the solution of a particular problem (Rütten, 2015, p. 165). To complete the brainstorming procedure first the initial problem is written down, then the group starts with the generation of ideas. The ideas are written down in sticky notes and organized in a chart. To realign focus, the ideas are checked after a certain period of time to verify they are heading in the right direction.

When a reference system is available, it is also useful to analyze the existing requirements that are usually collected in the requirement lists. Documenting requirements is very common in development projects. Requirement lists are very helpful tools that structure all requirements and make them available for future use. The requirement lists aim to provide a clear and structured documentation of the requirements for the product to be developed (Lindemann, 2009, p. 244). Ponn & Lindemann (2011) affirm that the requirements that the new product will have to meet should be documented in a requirements list considering the following aspects:

- Clarification of the list and eliminate discrepancies and repetitions.
- Identification of conflicts (interactions between requirements that cannot be met at the same time).
- Determination of priorities.

The goal of this stage is to collect both the physical requirements of the product structure and the functional requirements of the functional structure with the help of the reference system to adapt it afterwards for the future Product-Service System (see Figure 4-2). The input of this stage is the requirements of the reference system, which is usually presented in a requirements' list, and the output is another list with the requirements of the future PSS.

Figure 4-2: Existing reference system requirements identification and analysis

4.2.2 Existing reference system contextual factors identification

One of the most challenging aspects of companies is dealing with the actual complex and dynamic temporal behavior of elements from both inside and outside the organization. Different stakeholders are involved when combining products and services. (Resta & Gaiardelli, 2015, p. 2125). PSS offering requires "the coordination of manufacturing systems, maintenance, spare parts, logistics systems and so on" (Slack, Lewis, & Bates, 2004, p. 384).

Hence, the complexity of PSS involves not only internal but also external actors. According to (Bauer, 2016, p. 2), the changing environment that companies have to deal with includes stakeholders' needs such as changing customer demands, markets, legal and social systems, a dynamic of competition and continuous development of deployed technologies.

With the purpose of organizing the contextual factors affecting the planning of a new Product-Service System, an arrangement is suggested in this chapter. The classification reveals essential dimensions of factors and works as a foundation for further research and also as a summary for the designers to recognize relevant factors during the planning of future PSS enhancing the outcome quality. For the identification of the contextual factors affecting the development of the new PSS, techniques like PEST can be used.

PEST analysis is a tool used for analyzing strategic risk. It is the acronym for four sources of change: political, economic, social and technological. It identifies the contextual factors in the external environment of a company. Even though these variables are beyond the control of the firm, they should be taking into account to better adapt to the environment (Sammut-Bonnici & Galea, 2015). In this thesis, an advanced PEST analysis is proposed.

In order to include the analysis of internal factors, the classification shown (see Figure 4-3) is nor restricted to the PEST analysis. The element "others" is added to the scheme to include megatrends and industry-specific influencing factors. The result of this method is a chart with a summary of the most important contextual effects with an impact on the development of the PSS (see Figure 4-3). This result represents a situation of the environment before the implementation of the PSS ideas.

The presented classification should be used as a checklist for identifying factors in the reference system and serve as a basis to present the selected elements in an organized way.

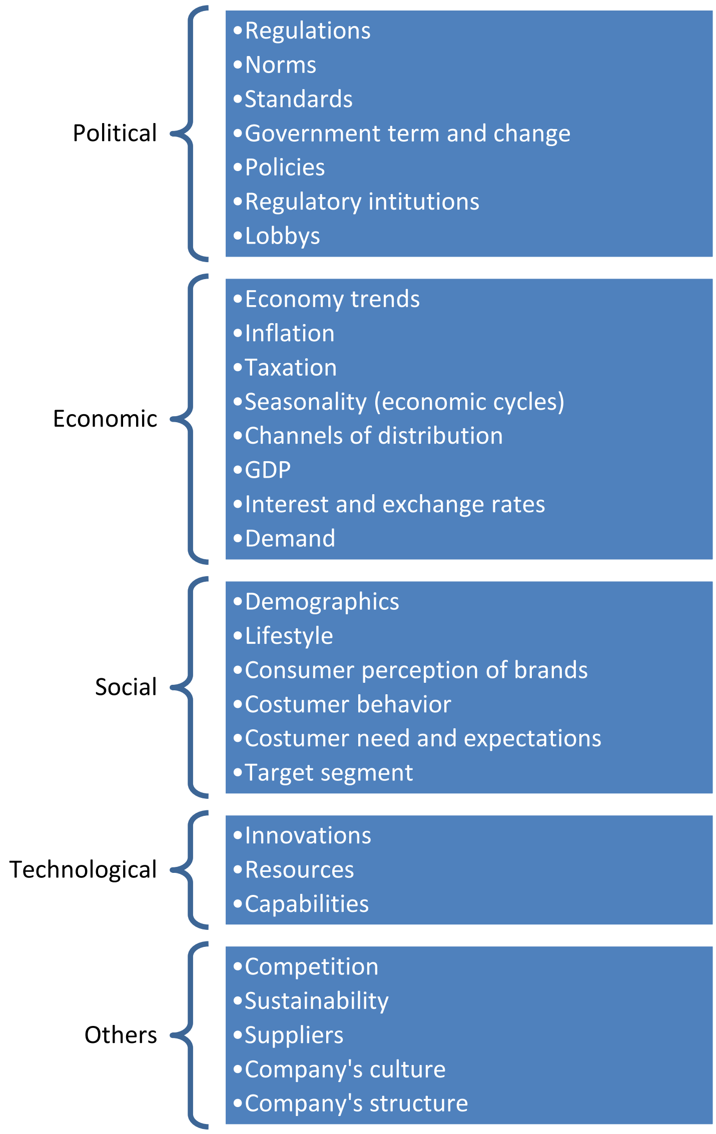

Figure 4-3: Proposed classification of contextual factors

- Political factors: The extent to which legislation affect the development of a new PSS is a crucial factor. Companies benefit from the study of the future political environment they will move in. These circumstances should be continually controlled because significant variations in the political resolutions may cause big changes in the environment the product is being developed (Sammut-Bonnici & Galea, 2015, p. 1).
  Obligations to adopt regulations, norms and standards derive in more standardization and uniformity (Joha & Janssen, 2014, p. 56). It is necessary to know whether to take into account specific regulations when designing a new product (e.g. emissions standards, health and safety regulations, taxation law). Generally, a document collecting significant regulations for previous products is available. This serves as a foundation for the new product being developed. During this process, it is necessary to control whether these regulations still apply to the new product (Lindemann, 2009, pp. 94–97).

- Economic factors: They have the greatest impact on the profitability. Factors arising from the market frequently point to fewer innovations as they often act as barriers to change (Hepperle et al., 2010, p. 1103).
  Companies decide to develop new products if they think their selling potential is high enough. According to Zakić et al. (2008), "the most important characteristics of the demand that a company should consider are: selling potential, demand growth, demand length, demand indefiniteness and demand elasticity." (p. 20).
  Driven by other factors such as sustainability, markets are constantly changing (e.g. automotive industry is shifting from combustion engines to electric vehicles) (Umeda et al., 2012).
- Social factors: They include work patterns, attitudes, preferences and behaviors. Customer needs and expectations, are essential for process innovations. As it was already discussed the current orientation of companies is towards customers, and not products anymore, which is one of the reasons for the increasing importance of PSS.
  This concentration on final customer needs implies the tracing of their satisfaction and gives companies a hint about future needs. Customer behavior is another influencing factor. A lot of work regarding this issue exist, particularly within economic sciences concerning the research of "Technology Acceptance Modelling" (TAM) (Hepperle et al., 2010, p. 1104). Differentiation between concentrating on a collective customer group or a more precise target. More customization is required when focusing on a specific target group. Anyway, it exists a trend of standardizing the base of the products and personalize them afterward to differentiate it from the competition (Joha & Janssen, 2014, pp. 56–57).
- Technological factors: Technological importance (what is the expected contribution), technological performance (improvement of existing and fulfillment of new functions), technological feasibility (possibility of technologic completeness) (Zakić et al., 2008, p. 21). They can include financial resources, human resources, or competences within the company.
- Other factors:
  - Competition: There are several approaches in the literature about how competition affects the future development of products. Many authors hold the idea of market concentration as a stimulus for other companies to innovate (Zakić et al., 2008, p. 24).
    Several aspects regarding the competitive context during the planning of a new product are identified: danger of competitors duplicating the technology and improving the delivered solution (e.g. if patents have not been guaranteed yet), presence of alike goods on the market (e.g. decrease of the selling price); unexpected appearing competitors (Hepperle et al., 2010, p. 1104).
    In this context the so-called cannibalization of current portfolio also takes place (it could be beneficial to the company to wait till the saturation point of the previous generation).
  - Sustainability: The combination of services and products reduces the

environmental impact. PSS improve product functionality while decreasing resources consumption. This is achieved through the introduction of ideas like leasing, renting, upgrading and maintenance into the development of new solutions (Ostrom et al., 2010, p. 11). Sustainability brings in interactions of the stakeholders that seek environmentally and socio-ethically innovations (Vezzoli et al., 2014, p. 50).

- Suppliers: In some cases, not all parts in the development process depend on only one company; very often, some parts are outsourced to a third party. There is limited opportunity for customization of the product if some elements have been outsourced and the relations with the suppliers become of great importance (Joha & Janssen, 2014, p. 58).
- Company's culture: The culture of the company has a great influence on the development of new products. First of all, it is required to analyze whether the new product fits with the image of the company and the current portfolio (Hepperle et al., 2010, p. 1104).
  Due to the increasing complexity of products and services, companies should enhance their innovation processes in order to be productive. Regarding the organizational culture, the manner the people in charge deal with their team also affects the development of new PSS (e.g. innovative ideas are hard to develop in environments of pressure and excessive control).
  It is also important to analyze whether lower hierarchical positions are able to decide during the development process. The history of the company is another aspect conditioning the way a product develops (e.g. difficulties on the launch of previous products might reduce the interest for innovation). (Hepperle et al., 2010, p. 1103).
- Company's structure: A flexible organizational structure that guarantees the flow of information among departments is fundamental to the success of new projects (Hepperle et al., 2010, p. 1103).

The goal of this stage is to collect the contextual factors of the reference system in a list, to adapt it afterwards for the future Product-Service System (see Figure 4-4). The input of this stage is the contextual factors of the reference system, and the output is the contextual factors of the future PSS presented in a PEST analysis.

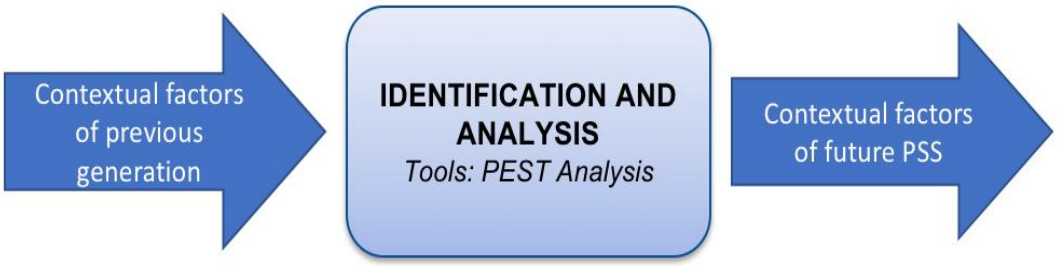

Figure 4-4: Existing reference system contextual factors identification and analysis

4.3 Prioritization and forecast

The collection of requirements and contextual factors should be available for PSS planners. After the first step is completed, a very large number of elements are identified, and this situation might not be useful for designers. In order to enhance the applicability of the collected elements, they can be combined and processed to serve as a final checklist. After identifying the requirements and contextual factors affecting the PSS, it should also be examined how they will change in the future and which ones are important for the company. Prioritization and forecast steps in this procedure are conducted simultaneously and in an iterative way.

In order to choose the appropriate factors to be studied for a specific time horizon, it becomes necessary to analyze whether their temporal behavior can be modified or not. Furthermore, the duration of the availability of the changes and their implementation in the development process should also be taken into account (Hepperle, 2013).

4.3.1 Adjustment to future Product-Service System

As the elements identified in the first step are just a raw collection, some of them are duplicates or not necessary for the analysis. The identification of influence factors may conclude with a considerable volume of information. It becomes necessary to structure this data in order to analyze it.

Hales & Gooch (2004) highlight the importance of the study of the context of a development project for its success. To support this task, they develop a design context checklist to identify the key influencing factors. Reymen et al. (2006) also address the need for examining the context of product development and suggest the utilization of a flexible checklist to specific situations. Not only context factors but also requirements require a prioritization.

Classifying requirements according to their importance permits the identification of priorities in the development process. To successfully prioritize the requirements of a PSS all fields of expertise should be covered: development, marketing, quality, purchasing, and production. Ponn & Lindemann (2011, p. 48) include in their study different approaches: one possibility is the distinction between demands and wishes. Another option is numerical weighting (Lindemann, 2009).

The existing models must be examined and adjusted in more detail according to the specific situation of the PSS of interest. After collecting and classifying the factors, the key elements should be identified. In order to anticipate possible changes, contextual factors should be associated to product requirements during the design phase. This link could ensure that the product will meet market demands in the future (Kammerl, Echle, & Mörtl, 2017).

There are different criterions to structure the collected factors and to graphically represent their relationships before carrying out and elaborate study that determines the key ones. The appropriate classification and prioritization of the influences can support the design process of PSS. In order to analyze and forecast future behaviors, it is necessary to reduce the number of factors that will be the aim of the study.

The proposed techniques for this stage are SWOT analysis, clustering, and customer and expert interviews. First, the large number of elements coming from the previous phase can be organized using a SWOT analysis and clustering techniques. Once the elements are grouped, customer and experts' interviews can be prepared and conducted to eliminate the redundant or not necessary factors.

- SWOT analysis: It is a method to analyze and represent the situation of companies relative to the market. It provides information about the company and its environment in a structured way. SWOT is an acronym for strengths (capabilities to be leveraged), weaknesses (characteristics that prevent the company to perform well), opportunities (ideas with capitalization possibilities), and threats (negative actions that should be mitigated).
  The external analysis involves the threats and the opportunities, while the internal analysis focuses on the strengths and weaknesses of the company (Harvard Business School, 2006, pp. 2–3).
- Clustering: Complex system with many parameters that determine correlations between elements. It serves to identify similar elements and classify them in multi-dimensional fields (Lindemann, 2009, p. 253). First, the elements are collected in a matrix. After that, consisted clusters in the matrix are searched to extract and analyze clusters. Finally, a summary of similar elements of a cluster are classified as a new element (Lindemann, 2009, p. 253). Figure 4-5 shows the procedure for clustering.

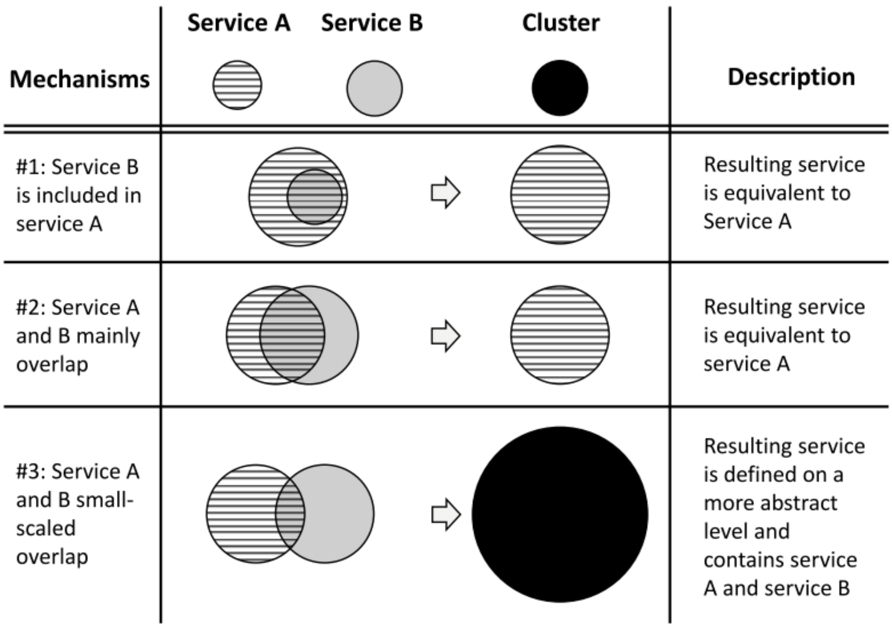

Figure 4-5: Mechanisms for clustering (Schmidt et al., 2015, p. 4)

- Customers and experts' interviews: Research of opinions and behaviors on specific topics. It serves to collect information about needs, experiences, behavior, and motivations regarding a particular offer or solution (Knapp, Zeratsky, & Kowitz, 2016; Lindemann, 2009, p. 272).
  Surveys help to determine explicit requirements of the stakeholders. It is a quite objective procedure, but the reports unavoidably depend on how and which questions are formulated as well as on the attitude of the respondent (Pohl & Rupp, 2010, p. 35). The procedure to conduct a successful interview is represented in Figure 4-6.

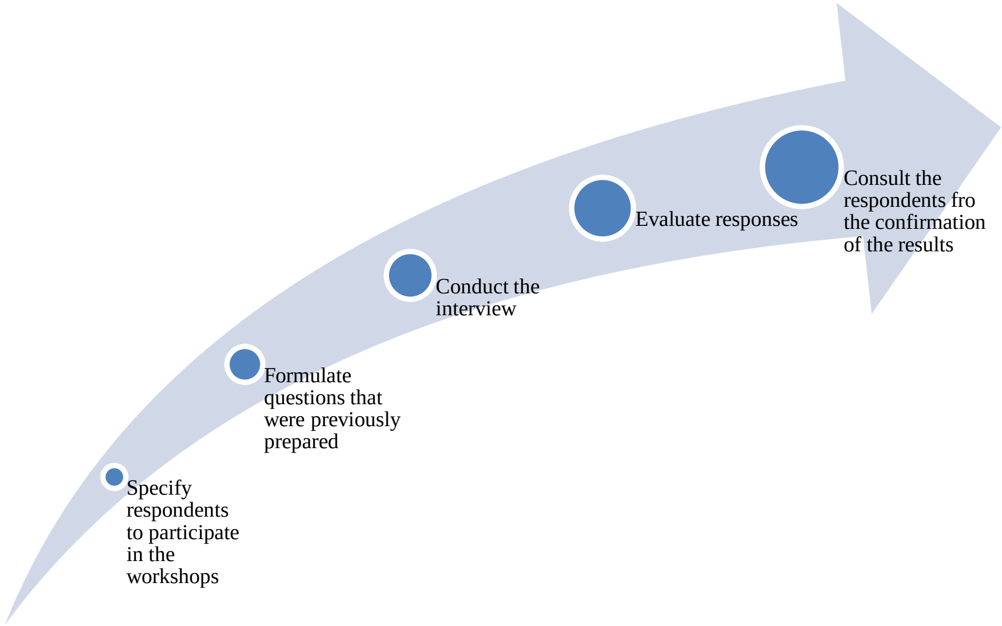

Figure 4-6: Customers and Experts Interviews procedure (Lindemann, 2009, p. 272)

The goal of this stage is to adjust the collected requirements and contextual factors from the previous step to the future PSS idea (see Figure 4-7). The inputs of this step are the list of requirements and contextual factors of the future PSS coming from the previous phase, and the output is a refined list, using the presenting techniques, and having as a result a shortlist with the adapted elements to the concrete PSS.

Figure 4-7: Requirements and contextual factors adjustment to future PSS idea

4.3.2 Selected aspects forecast

The forecast of the key influence factors is not the focus of this work because there is already existing literature covering this topic. Nonetheless, this anticipation is essential to the success of the development of a PSS. For this reason, some supporting methods that help to predict future behaviors are proposed later. The classification stage proposes a core for analyzing influence factors of PSS. Nevertheless, the requirement for an enhanced study that includes the dynamic features has not been discussed yet.

PSS are planned under present conditions, but they will be used in the future, as the development process takes its time. Therefore, the dynamic context should be taken into account when planning a PSS in order to consider the change that contextual factors could experience over time. One of the larger challenges when planning a future PSS is to deal with uncertainty. Once the influence factors have been reviewed and classified, the study of their dynamics is of essential interest, as this leads to uncertainty, and results in the need for adaptation during the innovation process.

The forecast of the temporal fluctuations of influencing factors is an essential element of this area (Langer & Lindemann, 2009). It is necessary to anticipate future developments and to react instantaneously and efficiently organize the adaptation to changing conditions in order to ensure the long-term success of cyclic processes.

The purpose of this chapter is to present a planning methodology that helps a designer to develop a new generation of PSS taking into account its context and the uncertainty of the future. There is a lack of related literature about models consolidating the prediction of the previously gathered factors. Alternative projections should be made in order to be prepared for responding to different future market situations or product structures presented (Lindemann, 2009).

The detailed model of collection of requirements and context factors helps to identify planning relevant circumstances. However, these factors show temporal behaviors themselves. Their understanding supports the knowledge of important information for future PSS (Hepperle et al., 2011, p. 344). The proposed techniques for the forecast of the collected elements are prognosis, scenario planning, and trends.

- Prognosis: Gathering of information about certain future events in order to make better decisions. It is composed by statements about future characteristics and its reliability depends on the input data and the performing method (Lindemann, 2009, p. 293).
- Scenario planning: Alternative future models based on the current situation. Analysis of the impact of future models selecting strategies and objectives for the planning of the product development (Lindemann, 2009, pp. 310–311). The procedure consists on the formulation of future projections of the selected factors to create scenarios from different groups of characteristics. After that, the scenarios and their effects should be analyzed (Lindemann, 2009, pp. 310–311).
- Trends: Statements about future developments with a likelihood of occurrence. It identifies long-term future developments, their causes and influences and helps for the strategic planning (Lindemann, 2009, p. 314).

The goal of this stage is to forecast the behavior of the collected elements in the previous stages (see Figure 4-8). The input of this step is the shortlist of the selected requirements and contextual factors adapted to the PSS. The output is the forecast of these requirements.

Figure 4-8: Selected aspects forecast

4.3.3 Essential aspects selection

This latest stage helps the planner to concentrate entirely on the significant factors for the success of the forthcoming PSS. The forecasted elements can be filtered again through quantitative tools like pairwise comparison, weighting, and influence matrixes. The elements that obtain the lowest scores can be eliminated, as they are not essential for the development of the future PSS. A qualitative tool that also could be applied on the selection of essential aspects is the 2x2 and SCRUM Matrix technique.

- Pairwise comparison: Quantitative valuation results with limited informative value. It compares solution alternatives and establish a ranking of given objects with regard to a specific criterion. The elements are compared in pairs in a preference matrix qualifying an element with better, worse or equal with respect to the other. Then, the values are added up and a ranking based on total

points is presented (Lindemann, 2009, pp. 287–288).
Weighting: Distinction of elements according to their importance and evaluation of solution alternatives (Lindemann, 2009, p. 269). A criterion composed by several elements is defined and a specific weight is given to every element (summing up 100% between all elements' weights). Each concept is then evaluated from 0 to 10 for each element criteria. The sum of the relative scores of the elements of each concept is noted in the last row. The concepts with the highest scores are the key concepts to take into account.
Table 4-2 represents an example of how to proceed with the weighting technique.

Table 4-2: Weighting example

CRITERION	**WEIGHT**	Concept 1	Concept 2
Element 1	60%	5	6
Element 2	40%	2	3
TOTAL	100%	5*0,6+2*0,4=3,8	6*0,6+3*0,4=4,8

- Influence matrix: The influence matrix is the basis for the definition of suitable development priorities. It determines the kind and intensity of mutual influences among elements (Lindemann, 2009, pp. 257–258). The elements are documented in an influence matrix in the first column and the first row. If the element of the row influences the element of the column the cell should contain a "1", if not it contains a "0". The sum of the rows is called active sum, and the sum of the columns is called passive sum. This calculation provides the activity of each element, which is a ratio used to compare elements (Kammerl et al., 2017, p. 4). An example of the procedure is shown in Table 4-3.

Table 4-3: Influence matrix example

Influence	Element 1	Element 2	Element 3	Element 4	**Active Sum**	**Activity**	**Criticality**
Element 1	X	2	0	1	**3**	**3**	**3**
Element 2	0	X	1	1	**2**	**0,5**	**8**
Element 3	1	2	X	0	**3**	**1**	**9**
Element 4	0	0	2	X	**2**	**1**	**4**
Passive Sum	**1**	**4**	**3**	**2**	**-**	**-**	**-**

- 2x2 and SCRUM matrix: Combination of methods to select, evaluate, and approve prioritization of ideas in a qualitative manner. It supports brainstorming processes in the selections and prioritization of appropriate ideas (Rustler, 2016). It is an iterative and customer-oriented process that uses the principles of agile (Grande, 2014, p. 113). Figure 4-9 represents the procedure to follow to conduct a 2x2 and SCRUM matrix analysis.

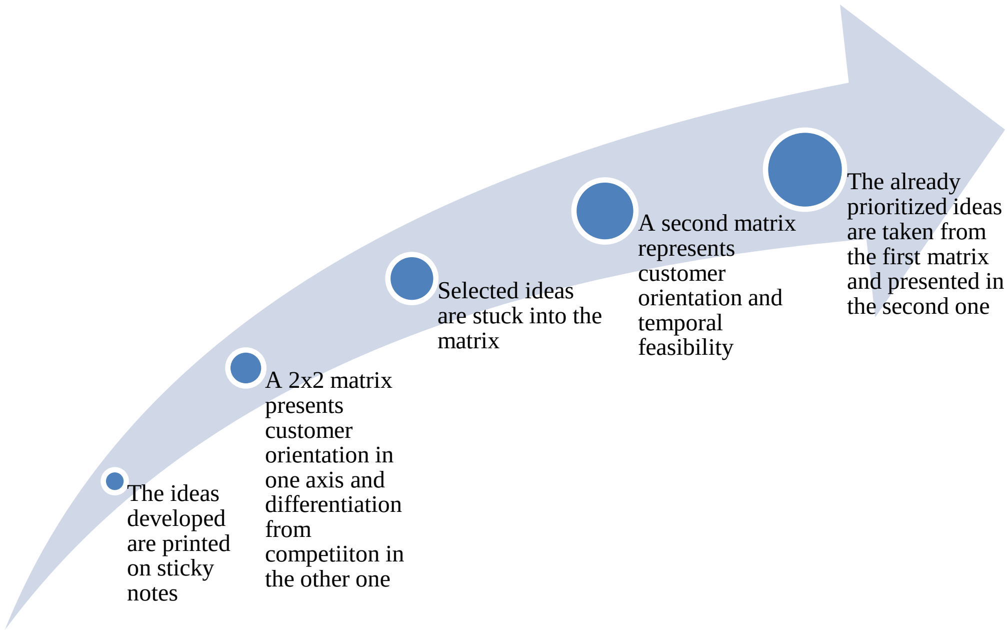

Figure 4-9: 2x2 and SCRUM Matrix procedure (Rustler, 2016)

The goal of this stage is to present a list of the essential aspects for the development of future PSS, taking into account their future behavior (see Figure 4-10). The input of this step is the forecasted requirements, and after the prioritization techniques presented in this step are completed, the output will be the key forecasted requirements for the development of the future PSS.

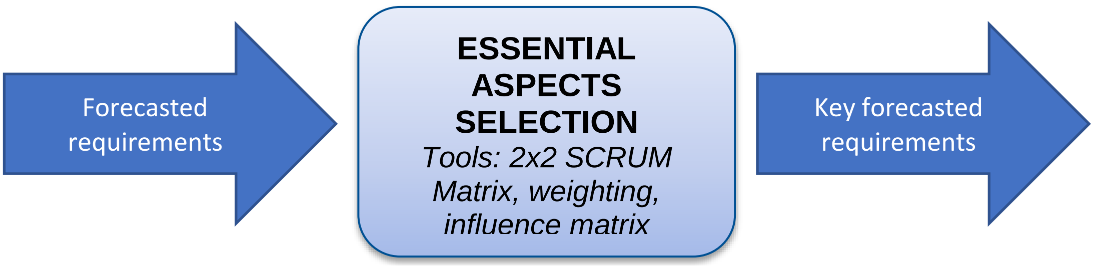

Figure 4-10: Essential aspects selection

4.4 PSS implementation and evaluation

The key forecasted requirements are those chosen for their criticality in the development of the future PSS. Weidmann et al. (2018) affirm that preceding studies demonstrate how requirements work as the interdisciplinary foundation for the PSS concretization.

In the following stages, the approach developed in this chapter should be implemented and evaluated according to the ability to satisfy the requirements of the PSS. The proposed key requirements coming from the previous step should be evaluated using one of the following techniques: service blueprint, value proposition canvas, and pairwise comparison.

- Service blueprint: Schematic representation of the service provided taking into account the customer and supplier viewpoints. It is the basis for design, control and development of services and it is usually used for testing the service prototype (Shostack, 1984). A blueprinting diagram template is shown in Figure 4-11.

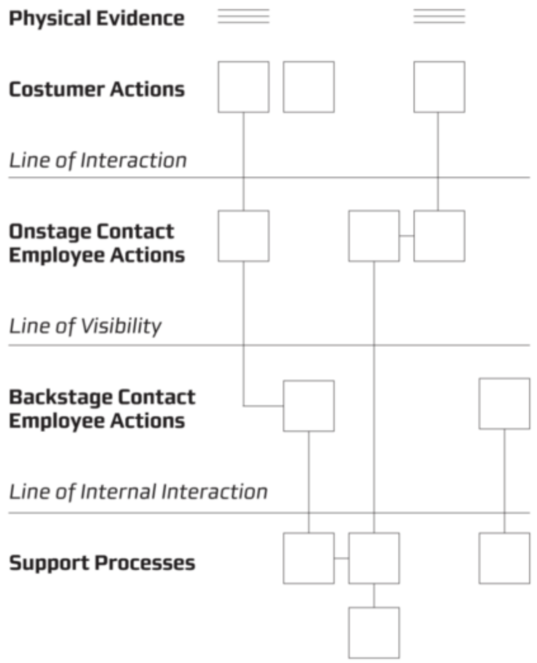

Figure 4-11: Blueprinting diagram (Zeithamal & Bitner, 2000)

- Value proposition canvas: Scheme with a comparison of value offer and customer needs. It helps to meet customer needs because the value offer of PSS is contrasted and adapted to the specific target market (Osterwalder, Pigneur, Smith, & Bernarda, 2014).

5 Discussion and limitations

5.1 Discussion about the results

The procedure developed in this thesis should be evaluated according to the capacity to meet the requirements listed in chapter 4.1. These elements constitute a comprehensive approach of a PSS (requirements 1 and 2), support the planning process (requirement 3) taking into account different planning horizons (requirement 4) with a future-oriented perspective (requirement 7) and focusing on the key elements (requirements 6). Furthermore, the procedure should be traceable (requirement 8) and the connections between the requirements and the contextual factors should be described (requirement 9).

The analysis of the results achieved in this thesis are summarized in Table 5-1. The completeness of the tasks is scored with a 0 (not addressed in the thesis), a 1 (partially addressed) or a 2 (completely developed in the thesis).

Table 5-1: Fulfillment of requirements for the developed procedure

Requirements of the procedure	Results	Comments
1. Gathering and classification requirement tools	1	Tools available in literature are presented
2. PSS perspective	2	Focus only on Product-Service Systems
3. Planning support	1	Although this procedure is intended to support designers, its validity is not proved with the help of an industry application
4. Consideration of different temporal horizons	1	
5. Gathering and classification tools of contextual factors	2	Original approach for the classification of contextual factors is developed
6. Prioritization tools	1	Tools available in literature are presented
7. Forecasting tools	1	Tools available in literature are presented
8. Traceability	2	The presented procedure is graphical and easy to follow
9. Interdependencies contextual factors-requirements	1	

5.2 Discussion about the procedure

The major challenge of this thesis is to provide a generic methodology that could be applied for all PSS. These kinds of offers are very diverse, and their success depends on specific elements that could not be identified in this thesis. Concentrating in a specific product, or even in a concrete field of the industry would have helped to provide a more detailed solution. This model is intended to be used a basic resource that can be easily adapted to the individual characteristics of the product the planner intends to develop. However, it cannot be guaranteed that every requirement and contextual factor has been identified.

The use of industry cases would help to define more precisely the application of the model. For example, by making it easier to identify any difficulties or lack of information on the application of the different stages. It will also help to connect the steps of the procedure in a more visual way, as a unique, continuous application could be performed.

Finally, an expert evaluation would be useful to validate the applicability of the methodology in a company.

6 Summary and outlook

6.1 Summary

In this paper, a design procedure for the development of future PSS was proposed. PSS are becoming very popular as companies shift their portfolios from a product-oriented to a service-oriented point of view (Aurich et al., 2005). Uncertainty is an important issue on the design of new offers (Stefan Langer & Lindemann, 2009, p. 539). The proposed procedure intends to support the designers in the process of finding and analyzing the requirements and contextual factors that will determine the success of their idea.

A review of existing approaches was conducted to find possible classifications of the elements affecting the PSS. A compilation of both requirements and contextual factors proposed by different authors is given. Nevertheless, new classifications are suggested in the scope of the developed procedure. This procedure is presented with a focus on the connection between the requirements of the PSS and the contextual factors that will affect them over time.

Research conducted on this thesis is enclosed in a larger context of developing PSS. Nonetheless, the focus of this thesis is not principally on the development process, but on the identification, classification and prioritization of contextual factors influencing it. Many factors are identified and connected to the PSS through its requirements. The presented procedure in chapter 3 provides an overview of how to deal with these elements. The evaluation of the developed procedure is then presented in chapter 5 with an exhaustive discussion of both the results and the procedure.

6.2 Outlook

In this section some of the potential next steps to develop within this procedure will be mentioned. Firstly, the proposed procedure validation in a real industry use case in order to verify its usefulness, this should be done through acquiring data and observing its behavior with respect to the expected outcome. This validation should be corroborated through various use cases covering a wide range of industries, in order to be able to statistically verify its usefulness and standardization for any PSS implementation.

It is to be noted that this data acquisition and validation should be undertaken at various planned time points as product cycles tend to be long. Additionally, an exhaustive comparison of all proposed tools should be done within the scope of this procedure, this will allow the correct tool selection depending on the PSS of study.

7 Glossary

B2B: Business to Business

DRM: Design Research Methodology

DS-I: Descriptive Study I

DS-II: Descriptive Study II

ICT: Information Communications Technology

IT: Information Technology

iPeM: Integrated Product Engineering Model

LC: Long Cycle

PEST: Political, Economical, Socio-Cultural, Technological

PS: Prescriptive Study

PSS: Product-Service System

RC: Research Clarification

RDMod: Requirements Data Model

RQ: Research Questions

SE: Service Engineering

SWOT: Strengths, Weaknesses, Opportunities, Threats

TAM: Technology Acceptance Modelling

UNEP: United Nations Environment Program

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