UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

ESCOLA DE ENGENHARIA

PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

Diego Augusto de Jesus Pacheco

PROPOSTA DE UM MÉTODO DE REFERÊNCIA PARA O DESIGN DE SISTEMAS PRODUTO-SERVIÇO SUSTENTÁVEIS ORIENTADOS À ECO-INOVAÇÃO EM PMES: EM DIREÇÃO À ECONOMIA CIRCULAR

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Tese submetida ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul como requisito parcial à obtenção do título de Doutor em Engenharia, na área de concentração de Sistemas de Qualidade.

Orientador: Profa. Dra. Carla Schwengber ten Caten

Porto Alegre

2017

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

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CIP - Catalogação na Publicação

Pacheco, Diego Augusto de Jesus
PROPOSTA DE UM MÉTODO DE REFERÊNCIA PARA O DESIGN DE SISTEMAS PRODUTO-SERVIÇO SUSTENTÁVEIS ORIENTADOS À ECO-INOVAÇÃO EM PMES: EM DIREÇÃO À ECONOMIA CIRCULAR / Diego Augusto de Jesus Pacheco. -- 2017.
450 f.

Orientadora: Carla Schwengber ten Caten .

Tese (Doutorado) -- Universidade Federal do Rio Grande do Sul, Escola de Engenharia, Programa de Pós-Graduação em Engenharia de Produção, Porto Alegre, BR-RS, 2017.

1. Inovação. 2. Sustentabilidade. 3. Engenharia de Serviços. 4. Sistemas Produto-Serviço. 5. Economia Circular. I. Caten , Carla Schwengber ten , orient. II. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

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Esta tese foi julgada adequada para a obtenção do título de Doutor em Engenharia e aprovada em sua forma final pelo Orientador e pela Banca Examinadora designada pelo Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul.

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Dedicatória:

Dedico esta tese à minha família, aos meus filhos, meus amigos, meus alunos, aos homens de bem que creem em Deus e aos que acreditam na força do Rio Grande do Sul e no futuro da Pátria amada Brasil.

AGRADECIMENTOS

Os desafios de desenvolver uma tese de doutorado ensejam diversos agradecimentos. Em primeiro lugar eu agradeço a Deus pela saúde e proteção. Agradeço a minha família, amigos colegas de trajetória acadêmica. Agradeço à UFRGS, à minha orientadora Profa. Carla, ao Prof. Jung, aos professores e aos colegas da UFRGS que participaram em alguma etapa dessa pesquisa. Agradeço aos amigos da UNIDEMI da Universidade Nova de Lisboa, em especial à Prof. Helena, à Prof. Alexandra, ao Prof. Virgílio e a todos que enriqueceram minha trajetória. Agradeço à Universidade de São Paulo e particularmente ao grupo de pesquisa do Prof. Henrique Rozenfeld pelas contribuições para essa pesquisa. Agradeço a Capes/CNPq pelo suporte e a todos os professores do PPGEP/UFRGS.

A mente que se abre a uma nova ideia
jamais volta ao seu tamanho original.
Albert Einstein

RESUMO

As lacunas de pesquisa encontradas na literatura evidenciam a necessidade de adotar métodos sistemáticos e estruturados no desenvolvimento da aferta do Sistema Produto-Serviço (PSS) e na geração de eco-inovações visando reduzir os riscos de inovação e aumentar o potencial da proposição de valor do PSS sustentável. Essa necessidade se torna ainda mais preemente para as pequenas e médias empresas devido às suas características intrínsecas e estruturais, tais como: sua capacidade restrita, lacunas de competências, falta de recursos, baixa qualificação da gestão, cultura interna, baixa competitividade, e assim por diante. Além disso, atualmente existe na academia um debate inconclusivo sobre o real impacto dos PSS nas três dimensões da sustentabilidade. Essa discussão evidencia que a sustentabilidade não é uma vantagem intrínseca dos modelos de negócios baseados em sistemas produto-serviços e que o PSS precisa ser projetado à luz da sustentabilidade. Como consequência dessa discussão, recentemente uma perspectiva promissora denominada *Sustainable Product-Service Systems* (SPSS) vem recebendo atenção da academia. Contudo, devido à novidade desse tema, o estoque de conhecimento disponível ainda é limitado. Portanto, a partir dessas lacunas da literatura, esta tese propõe um método de referência para suportar o design de propostas de SPSS orientados à eco-inovação em pequenas e médias empresas de manufatura. Os principais métodos de pesquisa adotados para atingir esse objetivo foram a revisão sistemática da literatura e grupos focados com especialistas em PSS e em pequenas e médias empresas. Como resultado principal da pesquisa foi possível desenvolver e validar um método de referência. Assim, os resultados dessa pesquisa minimizam as lacunas existentes na área de SPSS ao propor um artefato para ser usado por acadêmicos e profissionais que desejam elevar o potencial da sustentabilidade das ofertas de SPSS em pequenas e médias empresas.

ABSTRACT

The research gaps found in the literature highlight the need to adopt systematic and structured methods in the development of the Product-Service System (PSS) and in the generation of eco-innovations in order to reduce the risks of innovation and increase the potential of value proposition Sustainable PSS. This need becomes even more urgent for Small and Medium-sized Enterprises (SMEs) due to their intrinsic and structural characteristics, such as: their restricted capacity, skills gaps, lack of resources, poor management skills, internal culture, low competitiveness, and so on. In addition, there is currently an inconclusive debate in the academy about the real impact of PSS on the three dimensions of sustainability. This discussion evidences that sustainability is not an intrinsic advantage of business models based on product-service systems and that the PSS needs to be designed in the light of sustainability. As a result of this discussion, recently a promising perspective named Sustainable Product-Service Systems (SPSS) has been receiving attention from academia. However, due to the novelty of this theme, the stock of available knowledge is still limited. Therefore, from these literature gaps, this thesis proposes a reference method to support the design of SPSS proposals oriented to eco-innovation in manufacturing SMEs. The main research methods adopted to achieve this goal were the systematic review of the literature and focus groups with experts in PSS and in SMEs. As a main result of the research it was possible to develop and validate a reference method. Thus, the results of this research minimize the existing gaps in the area of SPSS by proposing an artefact to be used by academics and professionals who wish to raise the sustainability potential of SPSS offerings in SMEs.

SUMÁRIO

CAPÍTULO I

1 INTRODUCTION

Eco-innovation is the production, assimilation or exploration of a product, production process, service or method of management or business that is new to the organization (developing or adopting it) which results, over its life cycle, in the reduction of environmental risks, pollution and other negative impacts from the use of resources, including power, compared with corresponding alternatives (Kemp and Pearson, 2008). The debate on eco-innovation, although recent, is becoming increasingly more relevant in the practical context of business and academic world. It is an emergent topic between practitioners and academics.

In the eco-innovation categories suggested by Kemp and Foxon (2007), specifically the category 'eco-innovation in products and services with environmental benefits' consider products or environmentally improved products and environmentally beneficial services, such as solid and hazardous waste management services, water management, etc. Already in the Sehnem et al. (2016)' typology, the category 'system eco-innovations' comprehends a series of connected innovations improve or create entirely new systems with specific functions with a reduced overall environmental impact. As for example is a new Sustainable Product-Service System (SPSS) business model.

SPSS can be defined as "an offer model providing an integrated mix of products and services that are together able to fulfil 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" (Vezzoli et al., 2015, p. 2). Barquet et al. (2016a, p. 436) defined SPSS as "an approach to achieve benefits in the three dimensions of sustainability".

If compared with the publications on classical innovation topic, there are currently only a few numbers of studies about the management of technological eco-innovation and its processes (Ozaki et al., 2013; Klewitz and Hansen 2014). On the other hand, the discussion on eco-innovation in the context of

Small and Medium-Sized Enterprises (SMEs) is in a less developed stage and deserves attention. Unfortunately, the debate on eco-innovation and SPSS topcis has been widely discussed mainly in the context of large companies and mainly in industrial and technological sectors. The SMEs are considered a type of enterprise internationally relevant to the economy of nations. According to the Organisation for Economic Co-operation and Development (OECD), in a report from 2009, the SMEs make out between 96% and 99% of the total number of companies from EU and also contribute to a significant share of overall pollution. Hence, more investigations aiming to advance in the diffusion of eco-innovations in SMEs are necessary. Outcomes from literature also show that one important determinant to increase the diffusion of eco-innovations in SMEs is related to the absence of product and process eco-innovation oriented methods.

Structured methods are needed because systematic innovation methods for sustainable design reduce innovation risks (Kim and Park, 2012). Therefore, more systematic and structured managerial methods and tools must be adopted along with the servitization process (Rondini et al., 2016; Qu et al., 2016; Cavalieri and Pezzotta, 2012; Annarelli et al., 2016; Ceschin, 2014; Tukker and Tischner, 2006; Tukker, 2015) to mitigate, within others, the barriers associated with the “lack of knowledge within firms” (Vezzoli et al., 2015, p. 8).

Aiming to minimize problems associated with the need to support systematic innovations (Ceschin, 2013; Omann, 2003) and to solve contradictions and incoherencies (Barquet et al., 2016; Qu et al., 2016) during the servitization process, one alternative is the adoption of systematic innovation methods and tools to sustain a fluid transition process throughout the PSS stages. In this sense, Navas (2014) corroborated stating that enterprises need to invest in systematic eco-innovation methods if they plan to win or at least survive in competitive environments. In a nutshell, the gaps form literature shows that the background of literature available on the transition towards SPSS in SMEs is very fragmented, immature and insufficient to support a fluid transition process toward SPSS.

As a consequence, several gaps and seminal studies from literature pointed the need of proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and

End-Of-Life) in order to minimize the effects of lack of competence of SMEs and support the managers to conduce the transformation. Therefore, in order to fill these related research gaps, this present research identify the need of propose a reference method to support eco-innovation-oriented proposals of sustainable product-service systems for manufacturing SMEs. The next section detail how this research problem was approached in this doctoral thesis.

1.1 Research theme

The main theme of focus of this research is related to the method of SPSS proposals oriented to eco-innovation in SMES. The mains areas evolving are the following:

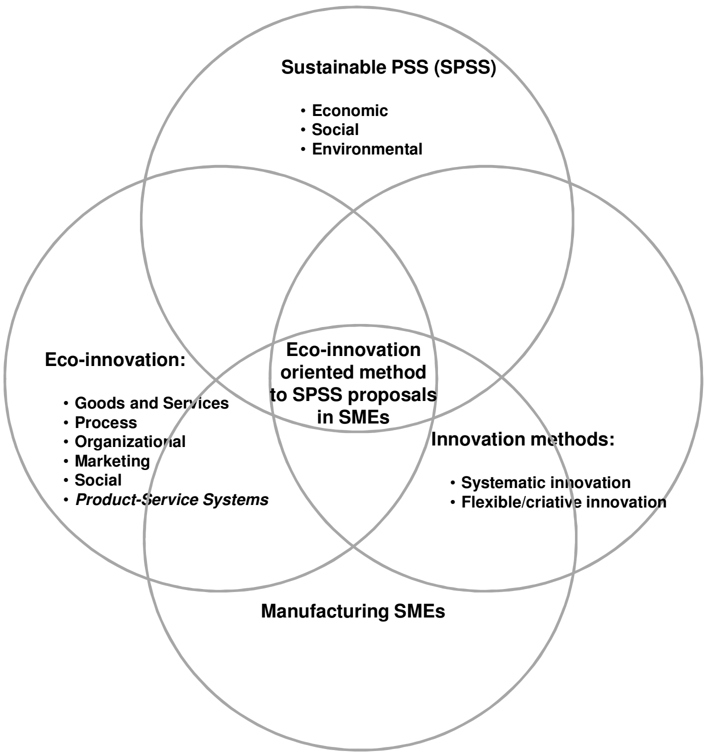

Fig.1. Research themes

1.2 General Objective

The general objective of this thesis is to develop a reference method eco-innovation-oriented to support proposals of sustainable product-service systems for SMEs.

1.2.1 Specifics Objectives

The specific objectives of this thesis are:

- Identify the key determinants and causal relationship between the eco-innovation determinants in small and medium-sized manufacturing enterprises.
- Understand the state of the art, elements and challenges related to the transition to product-service systems and to sustainable product-service systems.
- Understand the state of the art and key factors involving the transition process to sustainable product-service systems specificly in the context of small and medium-sized manufacturing enterprises.
- Analyse the potential of systematic innovation methods and tools to generate eco-innovations during the design of sustainable product-service systems.
- Identify appropriate systematic methods and tools to generating eco-innovation in the design of sustainable product-service systems in small and medium-sized manufacturing enterprises.
- Develop a reference method eco-innovation-oriented to support sustainable product-service system proposals in manufacturing SMEs, evaluating the proposed method and propose improvements.

1.3 Research gaps

The main research gaps available in the literature that were considered as drivers and motivation for the development of this research can be organized into categories and are presented in a synthetic manner as follows:

(i) Research gaps related to eco-innovation in SMEs:

- The integration of innovation and sustainability is a topic open for discussion in the literature. There are currently a number of studies on technological innovation and processes as well as studies about environmental sustainability. Nevertheless, there is relatively scarce research and few actions taken to integrate these two themes, which results in theoretical and methodological uncertainties to SMEs (Padula et al., 2015; Klewitz and Hansen, 2014; Triguero et al., 2004; 2013).

- Klewitz and Hansen (2014, p. 72) affirm that "[...] future research could try a more differentiated look at SMEs." In this sense, our research addresses the eco-innovation for manufacturing SMEs.
- Previous researches published in the leader journal on eco-innovation field, the *Journal of Cleaner Production,* are focused on different topics on eco-innovation in SME (Cai and Zhou, 2014; Klewitz and Hansen, 2014; Cuerva et al., 2014) and do not address specifically the proposition of a method integrating the PSS business models.

(ii) Research gaps related to SPSS:

- The SPSS concept seems to be a valuable and promising concept to tackle sustainability issues, but it does not represent a silver bullet. Thus, it is crucial to explore the potential synergies among SPSS and other promising and interwoven sustainability concepts (Vezzoli et al., 2015). In the case this research discusses the synergy with the eco-innovation concept.

(iii) Research gaps related to SPSS in SMEs

- The literature shows several evidences of which the transition towards SPSS is not an easy journey and that many difficulties hinder a sustainable servitization especially to SMEs (Vezzoli et al., 2015; Salazar et al., 2015; Kjaer et al., 2016; Pardo et al., 2013; Orloff and Heinz, 2015). A possible reason is that there are significant differences in innovation business models between large companies and SMEs. Policies as well as theories and instruments suited for large companies do not necessarily lead to successful outcomes within an SME. Another disadvantage is regarding the current research framework accumulating. The most part of literature focus mainly on large and often multinational companies, overlooking the significant contribution from SMEs.

- The existing background of literature for SPSS transition in SMEs are fragmented and insufficient to support a fluid transition process (Cook, 2014; (Vezzoli et al., 2015; Salazar et al., 2015; Pardo et al., 2013; Orloff and Heinz, 2015).

(iv) Research gaps related to need of reference Methods

- Regarding methodological uncertainties in SMEs, Navas (2014) stated that enterprises need to invest in systematic eco-innovation methods if they plan to win or at least survive.
- Although studies demonstrated the potential of systematic approaches, such as the TRIZ, in different topics on sustainability and cleaner production (Chechurin and Borgianni, 2016; Sperafico and Russo, 2015; Yang and Chen, 2011; Vidal et al., 2015) none study is focused specifically on the transition towards SPSS business models.
- Insights regarding how companies may adopt systematic methods to obtain a more systematic and sustainable servitization process are still very limited (Rondini et al., 2016; Qu et al., 2016; Cavalieri and Pezzotta, 2012).
- For some decades PSS have been known and acknowledged as effective means towards more sustainable production. However, despite several singular initiatives, PSSs have still not been implemented widely. Possible reasons for this failure to disseminate the concept are related with the lack of inappropriate supporting methods and tools (Annarelli et al., 2016; Ceschin, 2014; Cavalieri and Pezzotta, 2012; Tukker and Tischner, 2006).

1.4 Justifications and relevance of research

(i) Justifications and relevance of research relate to eco-innovation in SMEs

- While this research emphasizes manufacturing SMEs, the study by Klewitz and Hansen (2014), for example, does not discern the types of SME (manufacturing, services, commercial). Klewitz and Hansen (2014, p. 72) also affirm that "[...] future research could try a more differentiated look at SMEs."

- The discussion about eco-innovation is immature particularly in the SMEs context (Klewitz and Hansen, 2014; Rashid et al., 2015; del Río et al., 2015) and mainly in emergent economies (Govindan et al., 2016).
- More investigations aiming to advance in the diffusion of eco-innovations in SMEs are necessary (Klewitz and Hansen, 2014).

(ii) Justifications and relevance of research relate to SMEs context

- First, SMEs are considered a type of enterprise internationally relevant to the economy of nations. According to OECD, SMEs make out between 96% and 99% of the total number of companies from EU. Second, SMEs as a group contribute to a significant share of overall pollution. Third, SMEs are not simply smaller versions of their larger counterparts. Fourth, SMEs' peculiarities imply that they will innovate differently for sustainability. Fifth, the literature highlighting SMEs' disadvantages (e.g. resource constraints, lack of formalized planning) which may prevent them from engaging proactively in the innovation process showing reactive behaviour toward environmental and social issues.
- Findings from literature pointed the need of proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and End-Of-Life) in order to minimize the effects of lack of competence of SMEs and support the managers to conduce the transformation.

(iii) Justifications and relevance of research relate to SPSS topic

- There is in the literature the understanding that the sustainability is not intrinsic characteristic of PSS (Doualle et al., 2016; Pigosso and McAloone, 2016; Boucher et al., 2016; Kjaer et al., 2016).
- SPSS business models are expected to produce synergies in profit, competitiveness and environmental benefits and to renew stakeholder's

partnerships in a new convergence of economic interests and concomitant systemic resources optimization (Boucher et al., 2016) in an eco-efficiency perspective (Vezzoli et al., 2015). SPSS carry great potential to deliver social well-being and economic prosperity while operating within the limits of natural resources available (Vezzolli et al., 2015).

- "Because of the potential of SPSS to deliver social well-being and economic prosperity while operating within the limits of our planet, the research community has been inspired to analyse cases in diverse sectors, to increase the understanding of the potential benefits, drivers and barriers, and to develop and to test methods and tools to be able to enhance the array of SPSS that are implemented globally. This is urgently needed because, despite all the knowledge and experience that has been accumulated, there remain gaps in the research as well as a significant gap in how all this knowledge is transferred to implementation" (Vezzoli et al. 2015, p. 3).

(iv) Justifications and relevance of research relate to SPSS in SMEs

- The literature focused on this domain is scarce and, as a result, the operational deployment at the concrete level of the industrial SMEs economy are very limited (Clegg et al., 2017; Boucher et al., 2016; Nada and Ali, 2015; Pardo et al., 2012). To illustrate this aspect, a search by strings "Sustainable Product-Service System & SME" in Title field in Scopus database, returns only one single result. Hence, the hypothesis considered is that the debate of SPSS in SMEs is in a very immature research stage.
- The proposition of new methods, in the early stage of researches on SPSS in SMEs domain, is a relevant and necessary step to advance in innovative SPSS methods oriented to manufacturing SMEs.
- Some barriers related with low value products resulting in low profit margins can be a very critical factor in low incoming economies or in developing nations, where the normally the customers considerer the criteria cost as determinant for purchase. To overcome this barrier, more radical innovations based in radical value proposition are need. This may contribute to advance

in theory-building on SPSS transition in manufacturing SMEs in this specific context.

(v) Justifications and relevance of research relate to need of reference Methods

- To minimize problems associated with the need to support systemic innovation (Ceschin, 2013; Omann, 2003) and to solve contradictions and incoherencies (Barquet et al., 2016; Qu et al., 2016) during the servitization process, one alternative is the adoption of systematic innovation methods and tools to sustain a fluid transition process throughout the PSS stages.
- Structured methods are needed because systematic innovation methods for sustainable design reduce innovation risks (Kim and Park, 2012).
- More systematic and structured managerial methods and tools must be adopted along with the servitization process (Rondini et al., 2016; Qu et al., 2016; Cavalieri and Pezzotta, 2012) to mitigate, for example, the barriers associated with the "lack of knowledge within firms" (Vezzoli et al., 2015, p. 8).
- "In the transition process toward PSS, manufactures need the assistance of tools, techniques, and methods to provide superior service to customers" (Qu et al., 2016, p. 4).

1.5 Description of studies and procedures

This section presents the methodological outline and the research methods and procedures adopted to achieve the general objective, the specific objectives and the final results of this thesis in Engineering. Table 1 presents a synthesis to present objectively the studies and procedures adopted.

Table 1 – Structure of thesis

Objective	Research question	Research themes investigated	Research method	Techniques and type of research	Result	Thesis' Chapter
Identify the key determinants and the causal relationship between the main determinants for implementing eco-innovation in manufacturing SMEs. .	What are the key determinants of implementing eco-innovation in manufacturing SMEs? What is the causal relationship between the main determinants for implementing eco-innovation in manufacturing SMEs?	Definitions on eco-innovation. Classification of eco-innovation activities. Determinants to implement eco-innovation in SMEs.	Systematic review of the literature of the past 24 years. Systemic mapping framework.	Exploratory. Qualitative.	Paper 1	Chapter 2
Identify the key determinants of implementing eco-innovation in Brazilian manufacturing SMEs	What are the key determinants of implementing eco-innovation in Brazilian manufacturing SMEs?	Definitions on eco-innovation. Classification of eco-innovation activities. Determinants to implement eco-innovation in Brazilian SMEs	Systematic review of the literature of the past 20 years. Semi-structured questionnaire applied to ten Brazilian specialists in eco-innovation	Exploratory. Qualitative. Content analysis	Paper 2	
Understand the state of the art, elements and challenges related to the transition to Product-Service Systems and Sustainable Product-Service Systems.	What is the state of the art, elements and challenges related to the transition to Product-Service Systems and Sustainable Product-Service Systems?	Product-Service Systems. Sustainable Product-Service Systems. Systems Engineering and Product-Service Systems. Product-Service Systems and Sustainable Product-Service Systems: Benefits and barriers. Analysis of the evolution of the definitions Product-Service Systems and Sustainable Product-Service Systems. Successful Transition to Sustainable Product-Service Systems. Circular Economy.	Systematic review of the literature of the past 20 years.	Exploratory. Qualitative.	Paper 3	Chapter 3
Understand the state of the art and key factors involving the transition process for Product-Service Systems	What are the factors that involve the transition to Sustainable Product-Service Systems in	Characteristics of SMEs. Research techniques and tools to	Systematic review of the literature of the past 20 years.	Exploratory. Qualitative.	Paper 4	Chapter 4

and Sustainable Product-Service Systems in manufacturing SMEs.	SMEs?	support the transition. Results of transition cases. Barriers and lessons learned for the transition. Transition drivers and benefits. Challenges and e gaps research on the topic.				
Analyze the potential of systematic innovation methods to generate eco-innovations in the design of sustainable product-services systems proposals.	What are the main contributions and challenges for the application of systematic innovation methods in the transition to Sustainable Product-Service Systems?	Adoption of systematic TRIZ approach in Product-Service Systems and Sustainable Products-Services Systems. Main authors and studies. Context of application. Prospects and segment of companies. Eco-innovations obtained in Product-Service Systems adopting TRIZ. Challenges and e gaps research on the topic.	Systematic review of the literature of the past 20 years.	Exploratory. Qualitative.	Paper 5	Chapter 5
Identify systematic tools and methods to generate eco-innovation in sustainable product-service systems in small and medium-sized manufacturing enterprises.	How are TRIZ's systematic methods and tools applied to the transition to Sustainable product-service systems and can they contribute to a more efficient and systematic transition in manufacturing SMEs?	Systematic methods and tools of TRIZ. Types and classification of artifacts that adopt TRIZ's systematic methods and tools in product-service systems. Systematic artifacts, methods and tools used according to the types (Mont, 2002) of product-service systems. Purpose of the application of the systematic methods and tools available throughout the life cycle of products-services systems. Systematic methods and tools most frequently applied in product-service	Systematic review of the literature of the past 20 years.	Exploratory. Qualitative.	Paper 6	

		systems. Main advances, contributions and challenges on the use of systematic methods and tools in product-service systems.				
Develop an eco-innovation oriented method to support the design of Sustainable Product-Service System proposals in manufacturing SMEs.	How to develop an eco-innovation-oriented method to support Sustainable Product-Service System proposals in manufacturing SMEs.	Determinants for Eco-innovation in SMEs (Chapter 2). Factors involving the transition to sustainable product-services systems in general (Chapter 3). Factors Involving the Transition to Specific Sustainable Product-Service Systems in Manufacturing SMEs (Chapter 4). Systematic methods and tools that can contribute to a more efficient and systematic transition in manufacturing SMEs (Chapter 5).	Summary of the results of chapters 2, 3, 4 and 5. Literature review Focus Group 1 Focus Group 2 Focus Group 3	Exploratory. Qualitative Content Analysys.	Paper 7	Chapter 6

1.6 Implications and contribution of the thesis' chapters

The main implications and contributions of the Chapter 2 to the development of this thesis were the following:

- Were identified critical external and internal determinants to the successful adoption of eco-innovation practices in manufacturing SMEs by analysis of studies oriented to well mainly in well developed economies.
- The prevalence of a product and process eco-innovation oriented methods was one of critical determinants found.
- This chapter found as research gap the absence of alternatives to mitigate the impact of certain determinants in manufacturing SMEs that deserves deeper studies in the literature. One of these alternatives found is the application and integration of the PSS business models perspective on eco-innovation.
- Was possible identify critical external and internal determinants to the successful adoption of eco-innovation practices to the context of low economies, by investigating the context of the Brazilian SMEs.
- This study demonstrated a relative similarity between the eco-innovation determinants to well develop and in low economies.
- A list of several determinants and insights that justified the proposition of a reference method was identified.

The main implications and contributions of the Chapter 3 to this thesis were the following:

- The findings of this chapter made a theoretical contribution to PSS field clarifying the debate concerns the sustainable impact of PSS.
- This chapter exposed the foundations on which the limitations of PSS reinforce the controversy on its real sustainable impact to both companies and society.
- A very recent increase interest by 'sustainable product-service system' topic in past recent years was noted.
- Was confirmed the hypotheses that PSS and SPSS might be considerate distinct, although no totally independent disciplines.

- On one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. On the other hand, SPSS concept is based on eco-efficiency and in a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy.
- Hence, based in the previous benefits and in the impact on the society, SPSS discipline was included in the scope of this thesis.
- Was identified a research gap regarding how the tension between more sustainable and eco-innovators products and eco-services can be best managed was identified.
- Was identified a need of the proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and End-Of-Life) in order to minimize the effects of lack of competence of SMEs supporting the sustainable transformation.
- A special look to the SMEs should be given. They are a key actor to the global economy. At least 80% of all global enterprises are considered SMEs (Moore and Manring, 2009) and according to European Commission (2011) SMEs represent with over 99% of European enterprises and two-thirds of European employments.

The main implications and contributions of the Chapter 4 to this thesis were the following:

- Was possible to comprehend the factors involving the SPSS transition in manufacturing SMEs.
- Was found qualitative research techniques and the most functional tools most frequently employed in SPSS transition in SMEs.
- Identified internal barriers associates with intrinsic characteristics of SMEs become still more sensitive during the SPSS transition (e.g., limited financial resources, the lack of competences, follower mentality, resistance to change etc). These findings are similar to eco-innovation practices in manufacturing SMEs (Chapter 1, 2).

- The main barriers related with the novelty of SPSS business models require new attitudes to SMEs (e.g., change mind-sets from product ownership to use, replace value of exchange by value in use involving long term relations, lack of understanding of SPSS concept),
- Particularly the lack of models and methods guiding this transition was found as being one of main barriers related with the novelty of SPSS business models.
- Was found that the integration between service engineering structured tools with Business Model Canvas or Design Thinking approaches results in more effective methods supporting transition and helping to internalize some required competences in SMEs (Xing and Ness, 2016; Orloff and Heinz, 2015; Pardo, 2012).
- An innovative matrix supporting the decision making process by SMEs during the transition process to SPSS was proposed and incorporated in the method.
- Two corollaries emerged:

  Corollary 1: The transition process towards SPSS must be made incrementally instead radically.

  Corollary 2: The engagement of manufacturing SMEs in partnership and networks to develop the SPSS offers has potential to minimize the competence gaps and enable more innovative, complete and competitive value proposition to customers.
- This chapter offer a deep understanding on the SPSS diffusion in manufacturing SMEs and a comprehensive scientific support to trigger this transition

The main implications and contributions of the Chapter 5 to this thesis were the following:

- The research topic focusing on the systematic SPSS transition is far from being a mature research topic.
- There are no currently methodologies, methods or even reference models or methods accepted between the academics and professionals evolving in the servitization area. Thus, the systematic innovation proposals of TRIZ may

contribute to fill this research gap, enabling more systematic and sustainable PSS business models supported by structured methods.

- The proposition of new methods is a relevant and necessary step to advance towards effective SPSS business models, allying sustainable innovations and reduction in environmental impacts.
- Were identified guidelines about how the systematic methods and tools of TRIZ may be applied in the transition towards Systematic and Sustainable PSS (SSPSS) contributing to a more efficient and systematic servitization process.
- Aiming to expand the adoption of radical eco-innovations integrating TRIZ in SPSS it is necessary that artifacts have clear and detailed instantiations. Detailed instantiations, particularly within new and well organized TRIZ methods, are specially recommended.
- The suitable systematic methods and tools for SPSS design proposals and develop radical innovations in SMEs were mapped.
- This chapter presents the main systematic advances, contributions and tools to develop the proposed method to SPSS proposal oriented to eco-innovation in SMEs.

The main implications and contributions of the Chapter 6 to this thesis were the following:

- The previous accumulate results obtained in the chapters 2, 3, 4 and 5 were used as bottom line to conduce this stage of research.
- An eco-innovation-oriented reference method to support SPSS proposals for manufacturing SMEs was proposed and successively validates specialists in PSS field.
- Successive stages of enhance of the method, including or modifying tasks, phases, interactions between the phases and tools was developed.

1.6.1 Research methods

The research methods used to develop this thesis were based on several authors, according to the study proposal and the research questions to be answered.

In the paper 1 “Eco-innovation determinants in manufacturing SMEs: systematic review and research directions” the systematic literature review was conducted using the ten steps of the systematic review method proposed by Conforto, Amaral and da Silva (2011). To perform the data synthesis, the aggregative approach proposed by Tranfield, Denyer and Smart (2003) was employed to summarize findings. To obtain a deep understanding on the causal interactions among the determinants, a systemic map framework (Senge, 2006; Checkland, 2000) was developed to analyse and explored. Lastly, the literature review was validated using the protocol for systematic literature review proposed by Liberati et al. (2009).

In the paper 2 “Eco-innovation determinants in Brazilian manufacturing SMEs: literature review and challenges”, in order to conduct the systematic review of the literature, was adopted the research protocol suggested by Dresch et al. (2015). The research process adopted was the methodology proposed in Moher et al. (2009). The semi-structured questionnaire was organized according to Ribeiro and Milan (2007). The construction of the questionnaire followed the guidelines suggested by Hair et al. (2005) for content or face validity, being then validated through a small sample of respondents. The specialists’ responses were analyzed with content analysis process (Bardin, 2002).

In the paper 3 “Product-Service Systems and Sustainable Product-Service Systems: Two sides of same coin? Systematic review and research implications” was adopted as reference the research protocol suggested by Dresch et al. (2015) to develop the systematic literature review. The research process adopted was the methodology proposed in Moher et al. (2009). The synthesis based on the configurative analyses (Gough, Oliver and Thomas, 2012) was considered.

In the paper 4 “Sustainable Product-Service Systems in Small and Medium-sized Enterprises: State of the art and Challenges” was adopted as reference the research protocol suggested by Dresch et al. (2015) to develop the systematic literature review. The research process adopted was the methodology proposed in Moher et al. (2009). The process of synthesis of results was based on the configurative analyses (Gough, Oliver and Thomas, 2012) was considered.

In the paper 5 “Towards Sustainable Product-Service Systems: Systematic Review on the role of Theory of Inventive Problem Solving” was adopted as reference the research protocol suggested by Dresch et al. (2015) to develop the systematic literature review. The results of the research protocol are presented in four macro phases (Mayring, 2002). The paper 6 “Towards Systematic and Sustainable Product-Service System Design: State-of-the-art and research challenges” also adopted as reference the research protocol suggested by Dresch et al. (2015). The paper 6 “Towards Systematic and Sustainable Product-Service System Design: State-of-the-art and research challenges”. Finally, in the research entitled “A Eco-innovation-oriented Reference Method to Support SPSS Proposals for Manufacturing SMEs” three Focus Groups were realized following the protocol define by Hennink (2007). The qualitative content analysis of Focus Groups results was organized according to the protocol defined by Schreier (2014).

1.7 Research delimitations

The main research delimitations of this thesis are the following:

- First, considering that the practical diffusion of SPSS business models in both developed and low economies is restricted, the major challenges for transition remain in the context of manufacturing firms. Therefore, this research is delimited and oriented to manufacturing companies.
- Regarding manufacturing companies concerned, this research has its stages definitions and results oriented to all manufacturing segments (e.g. metalworking, furniture, plastic, etc.)
- The paper 2, “Eco-innovation determinants in Brazilian manufacturing SMEs: literature review and challenges” aim comprehended the eco-innovation determinants to low economies, as a whole. Nonetheless, by adopting the criteria of convenience, only the context of Brazilian SMEs was assumed as a low economy category.
- The main reference concepts adopted along this research are the following:
    - ✓ SPSS can be defined as “an offer model providing an integrated mix of products and services that are together able to fulfil 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” (Vezzoli et al., 2015, p. 2).

- ✓ Due the fact that the definition of SME varies from country to country, this study assume that a SME can be defined as independent businesses involved in the delivery of goods and services in a wide variety of industries and sectors. The term “SME” is used to group together businesses based on their size, that is measured financially and/or by the number of people employed in the business according to the country or region (Mitchell, 2014).

1.8 Structure of thesis

This thesis is structured in seven chapters. The first is an introductory chapter containing the description of research theme, the general and specifics objectives, the research gaps, the justifications and relevance of research, the description of studies and procedures adopted, main implications and contributions of the chapters, research methods, research delimitations, structure of these and publications achieved until the moment.

The chapter two contain two papers in eco-innovation topic. The paper “Eco-innovation determinants in manufacturing SMEs: systematic review and research directions” and the paper “Eco-innovation determinants in Brazilian manufacturing SMEs: literature review and challenges”.

The chapter three contain the paper “Product-Service Systems and Sustainable Product-Service Systems: Two sides of same coin? Systematic review and research implications”. And the chapter four contain the paper Sustainable Product-Service Systems in Small and Medium-sized Enterprises: State of the art and Challenges.

The chapter five contain the papers “Towards Sustainable Product-Service Systems: Systematic Review on the role of Theory of Inventive Problem Solving” and “Towards Systematic and Sustainable Product-Service System Design: State-of-the-art and research challenges”. And the chapter six “A Eco-innovation-oriented Reference Method to Support SPSS Proposals for Manufacturing SMEs”. The last chapter present the Conclusions, practical and theoretical implications of research, limitations and suggestion to further researches.

1.9 Partial publications

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Ribeiro, J. L. D.; Navas, H.V.G. ; Cruz-Machado, V. A. Eco-innovation determinants in manufacturing SMEs: Systematic review and research directions. Journal of Cleaner Production, v. 142, p. 2277-2287, 2016.

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G. ; Cruz-Machado, V. A. Systematic Eco-innovation in PSS: State of the Art and Directions. Procedia CIRP, v. 47, p. 168-173, 2016.

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G. ; Cruz-Machado, V. A. 2016. TRIZ in Servitization to Sustainable Product-Service Systems. Proceedings of 7th International Conference on Systematic Innovation (ICSI 2016), July, 2016, Lisboa, Portugal.

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G. ; Cruz-Machado, V. A. 2016. A TRIZ based method for Product-Service Systems in SMEs. Proceedings of 7th International Conference on Systematic Innovation (ICSI 2016), July, 2016, Lisboa, Portugal.

1.9.1 On going publicações:

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G.;Cruz-Machado, V. A. Eco-innovation determinants in Brazilian manufacturing SMEs: literature review and challenges. Submetido ao Jounal of Engineering and Technology Management (Qualis A1).

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G. ; Cruz-Machado, V. A. Towards Systematic and Sustainable Product-Service System Design: state-of-the-art and research challenges. Submetido ao Journal of Cleaner Production (Qualis A1).

Pacheco, D. A. J.; ten caten, C. S.; Jung, C. F.; Navas, H.V.G.;Cruz-Machado, V. A. Product-Service Systems or Sustainable Product-Service Systems: Two sides of same coin? Considerado para revisão na chamada de capítulos do livro “Managing Innovation in Highly Restrictive Environments - Lessons from Latin America and Emerging Markets”, Editora Springer.

CAPÍTULO II

The main implications and contributions of this Chapter to this thesis were the following:

- Were identified critical external and internal determinants to the successful adoption of eco-innovation practices in manufacturing SMEs by analysis of studies oriented to well mainly in well developed economies.
- The prevalence of a product and process eco-innovation oriented methods was one of critical determinants found.
- This chapter found as research gap the absence of alternatives to mitigate the impact of certain determinants in manufacturing SMEs that deserves deeper studies in the literature. One of these alternatives found is the application and integration of the PSS business models perspective on eco-innovation.
- Was possible identify critical external and internal determinants to the successful adoption of eco-innovation practices to the context of low economies, by investigating the context of the Brazilian SMEs.
- This study demonstrated a relative similarity between the eco-innovation determinants to well develop and in low economies.
- A list of several determinants and insights that justified the proposition of a reference method was identified.

2 Artigo 1: Eco-innovation determinants in manufacturing SMEs: systematic review and research directions

Abstract

The debate on eco-innovation, although recent, is becoming increasingly more relevant in the practical context of business and academic world. The discussion on eco-innovation in the context of manufacturing SMEs is in a less developed stage and deserves attention. Thus, the main objective of this research was to identify, through a systematic review covering the last twenty-four years, the determinants of eco-innovation in manufacturing SMEs, exploring the relationship among them. The study unveils twenty-three determinants, which were classified in seven categories. The critical determinants were also identified, comprising: Governmental policy supporting eco-innovation, Availability of resources (people, technology, knowledge), Perception of the strategic relevance of eco-innovation, Technological advisory oriented to environment, Product and process eco-innovation oriented methods, Cooperation and partnership within supply networks, among others. A systemic model representing the relationship among the determinants and strategic alternatives to overcome some eco-innovation barriers for manufacturing SMEs are also presented and discussed.

Keywords: Innovation, Eco-innovation; Manufacturing SME; Systematic review.

2.1 Introduction

Sustainable development and technological innovation are recurring themes in society, academic circles, and enterprises (del Río, Peñascoa and Romero-Jordán, 2016; Levidowa et al., 2015). The first studies on innovation date back to the propositions made by Schumpeter (1908; 1911; 1942). Innovation was first and clearly characterized by Schumpeter in his study "Theory of Economical Development", first published in 1911 in Austria. However, regarding environmental issues, it was the Eco92 in Rio de Janeiro, which established a historic landmark. Nevertheless, Blackburn (2008) states that the concept of environmental sustainability is not fully clear and there is still some confusion about this subject in business circles.

Blackburn (2007) and Carrilo-Hermosilla et al. (2009) discuss some aspects related to the history of sustainability referring the United Nations Conference on

Human Development in Stockholm in 1972. According to Mendonça et al. (2012), the term "sustainability" was launched at this conference. In relation to the discussion on the integration of innovation and sustainability, there are evidences of early studies conducted by Fussler and James (1996), James (1997), and Rennings (2000). Fussler and James (1996) have coined the term "eco-innovation" in the book entitled "Driving Eco-Innovation". They define eco-innovation as "new products and process which provide customer and business value but significantly decrease environmental impacts".

On one hand, the discussion on innovation has been strictly concerned about economic issues such as competitiveness, demand pressures and investment. On the other hand, the environmental area has hesitated to incorporate the processes of technological innovation (Przychodzen, 2015; Triguero et al., 2013; Levidowa et al., 2015; Cuerva et al., 2014; Simboli et al., 2014; Costantini et al., 2015). There are currently a number of studies on technological innovation and processes as well as studies about environmental sustainability, but there is relatively scarce research and few actions taken to integrate these two themes, which results in theoretical and methodological uncertainties to SMEs (Padula et al., 2015; Klewitz and Hansen, 2014; Triguero et al., 2004; 2013). About the methodological uncertainties, Navas (2014) stated that enterprises need to invest in systematic eco-innovation if they plan to win or at least survive.

The integration of innovation and sustainability is a topic open for discussion in the literature. In this scenario, the research on eco-innovation in the context of manufacturing SMEs is still incipient. The study by del Río, Peñascoa, and Romero-Jordán (2016) has identified that the leader journal on eco-innovation topic is the Journal of Cleaner Production. However, previous studies in the Journal of Cleaner Production (Cai and Zhou, 2014; Klewitz and Hansen, 2014; Cuerva et al., 2014) and in other journals (Carrillo-Hermosilla and Könnölä, 2010; Lee, Sameen and Cowling, 2015; Doh and Kim, 2014; Hottenrott and Lopes-Bento, 2014; McGuirk, Lenihan and Hart, 2015) are focused on different topics on eco-innovation in SME and do not address the drivers specifically in manufacturing based SMEs.

Generally, other themes are investigated in studies on innovation in SMEs context, such as innovation in services SMEs (Aykol and Leonidou, 2014), the importance of trademarks (Block et al., 2015), the impact of financial crisis (Lee, Sameen and Cowling, 2015), governmental financial aids for regional SME innovations (Doh and Kim, 2014), the effect of policy-induced strategies in SMEs (Hottenrott and Lopes-Bento, 2014; del Río, Carrillo-Hermosilla and Könnölä, 2010), SMEs innovation capacity (Boly et al., 2014), econometric methods (del Río, Peñascoa and Romero-Jordán, 2016), and the impact of innovative human capital (McGuirk, Lenihan and Hart, 2015). This confirms that the discussion on eco-innovation in SMEs is still emerging.

The importance of our research is corroborated considering the gaps pointed out by previous studies on eco-innovation in SMEs. While our research emphasizes manufacturing SMEs, the study by Klewitz and Hansen (2014), for example, does not discern the types of SME (manufacturing, services, commercial). Klewitz and Hansen (2014, p. 72) also affirm that "[...] future research could try a more differentiated look at SMEs." In this sense, our research addresses the eco-innovation drivers for manufacturing SMEs.

In this same direction, del Río, Peñascoa, and Romero-Jordán (2016, p. 1) state that "[…] analyses of the relevance of different determinants to eco-innovation for distinct eco-innovator and eco-innovation types have largely been missing".

Cai and Zhou (2014) and Triguero et al. (2013) also suggest as future studies the identification of eco-innovation determinants according to the type of industry. Considering the aforementioned gaps, the research question of the present study is: what are the determinants of eco-innovation in the context of manufacturing SMEs? In this sense, the contribution of our paper for the eco-innovation field is the identification and discussion of eco-innovation determinants in manufacturing SMEs.

To better understand the determinants and the relationship among the determinants for eco-innovation in manufacturing SMEs we carried out a systematic review covering the last twenty-four years. To Conforto, Amaral, and Silva (2011), Liberati et al. (2009), and Webster and Watson (2002), a systematic review contributes to the development of a solid knowledge base that (i) facilitates theoretical development in areas in which research has already been conducted, and (ii) allows the identification of opportunities for further research.

Our research aimed at understanding specific characteristics that prevail in manufacturing SMEs that have implemented eco-innovation, in addition to identifying driver and barriers for implementing eco-innovation. The research was conducted following the ten steps proposed by Conforto, Amaral, and da Silva (2011). A model following the systemic map framework approach (Senge, 2006; Checkland, 2000) was also developed to understand and explore the relationship among the determinants. The systematic literature review was validated through the application of the research protocol determined by Liberati et al. (2009) followed by an analysis and discussion of the studies identified. Finally, the conclusions were presented according to the research objectives.

This paper is structured as follow: after this introduction comprising the presentation of the research problem and objectives, section 2 presents the theoretical framework regarding eco-innovation definitions in SMEs; section 3 details the research methodology procedures and the steps of the systematic review; section 4 presents the results of the systematic review, while the discussion is presented in section 5; section 5 also presents the systematic review evaluation protocol; section 6 summarizes conclusions, limitations and suggestions for further research.

2.2 Defining eco-innovation

Before debating eco-innovation, one must be familiar with some definitions, presented in chronological order, that allow a better understanding of the variants and evolution of the concept. For instance, one of the first definitions was proposed by Fussler and James (1996) and James (1997) by suggesting that eco-innovation is considered a new product or process that adds value to the business and the customer, significantly decreasing the environmental impact.

To Rennings (2000), Kemp and Foxon (2007) and Arundel and Kemp (2010), eco-innovation can be defined as the production, application or exploration of goods, service, production process, organizational or managerial structure or method of business new to the enterprise or to the customer (OECD, 2009b). The desired outcomes are reduced environmental risks, less pollution, and fewer negative impacts of the utilization of resources when compared to the corresponding alternatives.

James (1997), Andersen (2008), and Foxon and Andersen (2009) bring in the idea of generating value by defining innovations that are capable of attracting green income in the market, reducing environmental impacts while creating value for the organizations. It involves the creation of new spaces in the market, products and services or processes led by questions of a social, environmental, or sustainability nature (Little, 2005). To Carrillo-Hermosilla et al. (2009), eco-innovation is a process of systemic, technological, and/or social change, which consists in the invention of an idea and its application in the practice of environmental improvement.

Reid and Miedzinski (2008) present a more detailed definition by saying that it is the creation of new and competitive efforts of products, processes, systems, services and procedures conceived to meet human needs and provide a better quality of life for everyone, with a minimum utilization of the life cycle of natural resources and a minimum release of toxic substances. The concept presented by Kemp and Pearson (2008) is similar since it states that eco-innovation is the production, assimilation or exploration of a product, production process, service or method of management or business that is new to the organization (developing or adopting it) and which results, over its entire life cycle, in fewer environmental risks, less pollution and other negative impacts from the use of resources, power inclusive, compared with pertinent alternatives. A more encompassing and current definition has been presented: "it represents an innovation which results in a reduction of the environmental impact, whether this effect is intentional or not" (OECD, 2009a).

It can be observed that the concepts presented between 1996 and 2009 vary considerably. Nevertheless, the ideas of reduced environmental impact, maintenance of life, and existing natural resources, associated with classic innovations of products, processes and practices of innovation management are recurrent. Foxon and Andersen (2008) also highlight that the practices of eco-innovation go beyond the mere adoption of low carbon technologies. In fact, they comprise the creation and application of new knowledge, involving values, rules and capabilities, as well as the creative destruction of ancient practices.

2.2.1 Classification of eco-innovation activities and practices

Eco-innovations can be developed by enterprises or by non-profit organizations; they can be transacted in market or not; and they may have a technological nature of reactive or preventive character (Rennings, 2000). The typology proposed by Rennings (2000) presents four classes of eco-innovation: technological, organizational, social and institutional. The group of technological eco-innovations is sub-divided into: i) reactive technologies, to repair damage (e.g., contaminated soils); and preventive technologies, to prevent environmental damage, or; ii) end-of-pipe technologies, comprising measure taken after the production and consumption processes; clean or integrated technologies, that treat the cause of emissions during the production process or at product level.

The organizational eco-innovations are defined as the changes in companies' management instruments (eco-audits) and innovations in services (management of power demand and waste transportation). They require, therefore, new infrastructure and system changes that reach far beyond the adoption of a certain technology. The third group consists of the social eco-innovations, concerning new patterns of sustainable consumption that have drawn increasing attention and are considered as changes in people values and their life styles for sustainability. Lastly, the institutional eco-innovations are characterized as innovative institutional responses to the problems of sustainability promoted by local networks and agencies, global governance, and international commerce. They are viewed as a fundamental basis for the sustainability policy.

Andersen (2008) classifies eco-innovations as follows: add-on, integrated, of alternative product, macro-organizational, and general-purpose. The add-on eco-innovations comprise technologies for resources management and services concerning pollution, which improve the environmental performance and are developed by the environmental sector. Integrated eco-innovations are processes and products technologically cleaner than their counterparts, which contribute for solving or mitigating environmental problems within the companies or in other organizations such as public agencies and families.

The eco-innovations of alternative products are the new technological trajectories that represent radical product innovations. The environmental dimension is rooted in conception and production, as is the case of renewable power technologies. Macro-organizational eco-innovations are organizational structures that imply new solutions to an eco-efficient form of organization of society. They comprise new ways of organizing production and consumption at a more systemic level, requiring new functional interactions between organizations. Lastly, the general-purpose eco-innovations are those technologies that deeply affect the economy and the process of innovation, contributing to other technological innovations and (re)defining the dominant techno-economic paradigm.

According to Kemp and Foxon (2007), eco-innovation can be classified as follows: environmental technologies, organizational innovations for the environment, innovations in products and services with environmental benefits, system of green innovations, and general-purpose technologies. Eco-innovations focused on environmental technologies are those associated with pollution control, clean production processes, waste management equipment, environmental monitoring and instrumentation, green power technologies, water supply, and noise and vibration control. Organizational innovations for the environment are organizational methods and management systems designed to deal with environmental issues in products and production, such as more efficient operation of processes, environmental management and audit systems, and the management of the value chain.

Innovations in products and services with environmental benefits would be new products or environmentally improved products and environmentally beneficial services, such as solid and hazardous waste management services, water management, environmental consultancy, engineering and testing, and analyses services. Green innovation systems are alternative systems of production and consumption that involve a set of changes in the production technologies, knowledge, institutions and infrastructures and, possibly, changes in consumer behaviour. Lastly, the general-purpose technologies possess certain configurations and types of environmental uses such as biotechnology and TICs (Kemp and Foxon, 2007).

From the analysis of the eco-innovation taxonomy, it is possible to identify some similarities between them. First, technological eco-innovations are presented in all classifications, quoted as the reactive or end-of-pipe technologies (Rennings, 2000), the add-on or technologies for resource management and sustainable services (Andersen, 2008) and the environmental technologies and products and services innovations (Kemp and Foxon, 2007). Another convergence between the typologies refers to organizational eco-innovations, quoted as organizational (Rennings, 2000), macro-organizational (Andersen, 2008), and organizational innovations for the environment (Kemp and Foxon, 2007).

Eco-innovations that change the values of people and their lifestyles for sustainability are classified by Rennings (2000) as social eco-innovations and in Kemp and Foxon (2007) as system of green innovations. Andersen (2008) and Kemp and Foxon (2007) also converge regarding the general purpose eco-innovations, considering them as technologies that change the economy by contributing to other technological innovations and defining techno-economic paradigms (e.g. biotechnology and TICs).

The classification proposed by Kemp and Foxon (2007) is wide in scope, since it includes the new environmental technologies, new products, services, organizational changes, management practices and general interest technologies such as biotechnology and TICs. In a general perspective, Andersen's typology (2008) is similar to Kemp and Foxon's (2007). It is important to note that the classification "integrated eco-innovations" does not correspond directly to Kemp and Foxon (2007) as it extends its scope to solutions of environmental problems within the organization or in other organizations such as public agencies and families.

Rennings's (2000) typology stands out as distinct from the others. It presents the idea that a number of factors are interdependent: social, institutional and organizational. An important aspect is that the three typologies discussed are not specific for companies' size (SME or larges companies) or type (service or manufacturing based companies). Perhaps this is because eco-innovation is an emerging theme. Hence, there are opportunities for future researches on eco-innovation oriented to manufacturing SMEs, which is the object of this paper.

2.3 Materials and Methods

This section presents the description of the steps adopted for the systematic review of the literature, with emphasis on the criteria used in the conduction of the study. According to Webster and Watson (2002), the literature review plays an important role in studies requiring a certain degree of unprecedented findings and originality.

Therefore, a thorough and systematic review of the literature can contribute to the development of a base of useful knowledge, to generate information about the areas of study, and to indicate new opportunities for research. Conforto, Amaral and da Silva (2011), Tranfield, Denyer and Smart (2003), Dyba and Dingsoyr (2008), Kolltveit, Karlsen and Gronhaug (2007) and Levy and Ellis (2006) also stress the importance of a systematic review to understand the state of the art about the research theme and to identify information gaps deserving deeper studies.

This study was conducted using the ten steps of the systematic review method proposed by Conforto, Amaral and da Silva (2011). In the data synthesis stage, the aggregative approach proposed by Tranfield, Denyer and Smart (2003) was employed to summarize findings. Moreover, a systemic map framework (Senge, 2006; Checkland, 2000) was developed to analyse and explore the relationship among the determinants of eco-innovation. In the last step, the review was validated using the protocol for systematic literature review proposed by Liberati et al. (2009). The steps of the systematic review are detailed as follows.

Step 1. Definition of the problem: what are the determinants of eco-innovation in manufacturing SMEs?

Step 2. Definition of the research objectives: to identify and discuss the determinants for eco-innovation in manufacturing SMEs.

Step 3. Primary sources: the primary sources for the review were the databases Scopus, Scielo, and Proquest. First, a thorough search was conducted for ‘eco-innovation’ and ‘SMEs’ to determine the word variants cited in published articles. Several terms were associated with eco-innovation (sustainable innovation, environmental innovation, green innovation, clean innovation, and ecology innovation), usually cited in studies on eco-innovation, which were incorporated into the research and used in the search strings. This also happened to the term SMEs (small firm, medium firm, SMEs, small business, medium business, small and medium sized business, small and medium sized enterprises, small enterprises and SME).

Step 4. Keywords or search strings: the search fields Summary and Title were searched with the use of all combinations of the primary sources listed in Step 3, to ensure a clear focus considering our research objectives. The keywords related to eco-innovations were: sustainable innovation, environmental innovation, green innovation, clean innovation and ecology innovation, eco-innovation. The keywords related to SMEs were: SMEs, small firm, medium firm, SMEs, small business, medium business, small and medium sized business, small and medium sized enterprises, small enterprises and SME. Some examples of combinations used in the search process are: eco-innovation & SMEs, eco-innovation & small and medium-sized enterprises.

Step 5. Defining the research timeframe: the period covered by the research was from January 1990 to December 2014.

Step 6. Inclusion and exclusion criteria: after reading the title and the abstract of the articles found in step 4, the following inclusion criteria were used: i) papers focusing on manufacturing SMEs; ii) theoretical review studies of eco-innovation in manufacturing SMEs; iii) studies on critical success factors for the implementation of eco-innovation in manufacturing SMEs; iv) research on advantages, benefits, and downsides of eco-innovation in manufacturing SMEs; v) case studies about the implementation of eco-innovation practices in manufacturing SMEs; vi) studies addressing a sample of SMEs presenting isolated results for SMEs. The abstract of fifteen papers did not clearly state the scope of the article, so it was necessary to read the main sections of these papers before selection. Papers discussing eco-innovation *per se*, papers on eco-innovation with quantitative and statistical bias, and articles with lower methodical rigor were not included.

Step 7. Article qualification criteria: papers included in Step 6 were carefully read and then selected or not considering the following qualifying criteria: i) research method utilized: in this sense, articles with multiple case studies and conceptual reviews were prioritized; ii) Journal Citation Report (JCR) greater than 1.0; iii) frequent citations of the article in the publications read throughout the research; iv) journals with double review process. After the analysis of twenty-eight papers, the following papers were selected: del Brío and Junquera (2003), Klewitz, Zeyen and Hansen (2012), Suh, Lee and Ha (2005), Gronum, Verreynne, Kastelle (2012), Sánchez-Medina, Corbett and Toledo-López (2011), Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010), Bos-Brouwers (2010), Mazzanti and Zoboli (2008), Talbot (2005), Miranda and Malachias (2012), Scarpellini et al. (2012) and Sánchez-Medina, Maçaneiro, Cunha and Balbinot (2013), Corbett and Toledo-López (2011), and Triguero et al. (2013).

Step 8. Method and tools: the definition of the search method and tools, comprising search conduction, search filters and storage of information. It had to contemplate cycles that facilitate the learning, refining of the search procedures, and cross searches starting from the references cited in the articles. The articles chosen in previous steps were investigated for understanding of the scope and classification.

Steps 9 and 10. Processing and output: final processing steps comprising the search *per se* applying the filters described in previous steps. A control spread sheet was prepared to document the findings. The final step of the method was the analysis and synthesis of the findings, which is discussed in detail in the next section. To realize this final step, was employed a systemic map framework (Senge, 2006; Checkland, 2000) to explore the relationship among the determinants unveiled by the literature review. Results are discussed in detail in the next sections.

2.4 Results

2.4.1 Descriptive analysis

The selected papers can be widely classified considering: (i) the theoretical theme in study (del Brío and Junquera, 2003); the use of single or multiple case studies (Talbot, 2005; Scarpellini et al., 2012; Sánchez-Medina, Corbett and Toledo-López, 2011; Mazzanti and Zoboli, 2008; Maçaneiro, Cunha and Balbinot. 2013; Suh, Lee and Ha, 2005); and the use of managers or experts as information source (Triguero, Moreno-Mondand Davia, 2013; Fernández-Viñé, Gómez-Navarro and Capuz-Rizo, 2010; Klewitz, Zeyen and Hansen, 2012; Gronum, Verreynne, Kastelle, 2012; Bos-Brouwers, 2010).

The selected papers were published in *Journal of Cleaner Production, Journal of Industrial Ecology, Technovation, European Journal of Innovation Management, Sustainability, Business Strategy and the Environment, Journal of Environmental Economics, Engineering Management Conference, Clean Technologies and Environmental Policy, Ecological Economics, Latin American Business Review* and *Journal of Small Business Management*. Research on SMEs manufacturing is distributed in a wide range of journals and there is no predominance of publications in any specific journal.

In spite of the wide temporal range (24 years), only a few studies on eco-innovation in manufacturing SMEs were identified. However, none of these studies focuses specifically on the determinants of eco-innovation in manufacturing SMEs. Regarding regions, a predominance of studies in Europe was observed. Mazzanti e Zoboli (2008) analyzed 257 SMEs from industrial sectors in northern Italy. Bos-Brouwers (2010) investigated 26 SMEs of the plastics and rubber sector that participate in the Prima Project in Holland. Seven Germany SMEs of metal-mechanics sector are analyzed by Klewitz, Zeyen and Hansen (2012). Scarpellini et al. (2012) and del Brío and Junquera (2003) also analyzed SMEs in industrial sectors in Europe. Triguero et al. (2013), for example, conducted a survey involving 5.222 managers of SMEs in the 27 EU Member Countries. Studies in other regions were also identified. For instance, the studies investigated one South Korean SME (Suh, Lee and Ha, 2005), 96 Canadian SMEs of the electrical and electronics segment (Talbot, 2005), 54 manufacturing SMEs from Venezuela (Fernández-Viñé, Gómez-Navarro and Capuz-Rizo, 2010), 168 Mexican companies (Sánchez-Medina, Corbett and Toledo-López, 2011), and 117 Brazilian manufacturing SMEs (Maçaneiro, Cunha and Balbinot, 2013).

Among the papers selected for the aggregate analysis, one study was published in 2003, 2005 and 2008, two studies in 2010, one in 2011, four in 2012 and two in 2013. We observed a growing trend in the number of publications on SMEs in the last years, since 70% of papers were published after 2010. An explanation for this fact can be that research on eco-innovation in SMEs is in an emerging stage and the understanding of this movement is still under construction (Andersen, 2008; Blackburn, 2007; Bos-Brouwers, 2010; Carrillo-Hermosilla, 2009; Triguero et al., 2013).

The results showed a trend regarding eco-innovation topics. The topic of eco-innovation management in SMEs is discussed in several studies (del Brío and Junquera, 2003; Klewitz, Zeyen and Hansen, 2012; Bos-Brouwers, 2010; Mazzanti and Zoboli, 2008; Miranda and Malachias, 2012; Sánchez-Medina, Corbett and Toledo-López, 2011). Other topics comprising eco-design and product life cycle (Talbot, 2005), eco-efficiency (Fernández-Viñé, Gómez-Navarro and Capuz-Rizo, 2010; Suh, Lee and Ha, 2005), drivers for eco-innovation (Triguero et al., 2013; Maçaneiro, Cunha and Balbinot, 2013) or R&D in SMEs (Scarpellini et al., 2012) are also discussed.

The results also showed a trend regarding the adopted research procedures. Several studies used survey or interviews with a large sample as the main research method. Talbot (2005) conducted a survey adopting a quantitative scale questionnaire. Maçaneiro, Cunha and Balbinot (2013) applied a quantitative approach using the strategy of a cross-sectional survey by means of a self-administered online questionnaire. Sánchez-Medina, Corbett and Toledo-López (2011) applied a survey based on a questionnaire and the collection of empirical data via Kaizer normalization. Mazzanti and Zoboli (2008) applied two surveys structured with analysis of reports and statistical validation. The survey in Triguero et al. (2013) was carried out covering companies of the Flash Eurobarometer project, reaching 5,222 companies. The use of interviews as the main research procedure was adopted by Klewitz, Zeyen and Hansen (2012). The study addressed SMEs managers of the Ecoprofit project. The combination of in-depth exploratory interview with questionnaires involving managers was also employed (Bos-Brouwers, 2010; Miranda and Malachias, 2012; Fernández-Viñé, Gómez-Navarro and Capuz-Rizo, 2010). Other research procedures, such as literature review (del Brío and Junquera, 2003) and various sources of quantitative data reports supported by literature evidence (Scarpellini et al., 2012) were also observed.

2.4.2 Content analysis

Results of content analysis based on systematic reviews show different research objectives on eco-innovation in SMEs studies. Talbot (2005) proposed to identify insights regarding the degree of eco-design adoption in Canadian SMEs. Del Brío and Junquera (2003) identified strengths and weaknesses of the public administration regarding their relationship with SMEs. The study was conducted comprehending the characteristics of eco-innovation management in SMEs. In a similar way, Bos-Brouwers (2010) and Maçaneiro, Cunha and Balbinot (2013) explored factors that may convert sustainable innovation into practice in SMEs.

Sánchez-Medina, Corbett and Toledo-López (2011) analyzed the relationship between environmental innovation and sustainability. In this same direction, Klewitz, Zeyen and Hansen (2012) identified the role of intermediaries in the SMEs search for corporate sustainability supported by eco-innovation. Drivers, barriers and effects induced by the collaboration between SMEs and local authorities or consultants were also investigated. Scarpellini et al. (2012) analyzed causes for the disconnection between public sector and private research on innovation in Spain. The study discussed improvements according to the R&D benchmark countries in Europe. In a similar way, Mazzanti and Zoboli (2008) identified evidences of eco-innovation practices in SMEs strategies and political regulations.

Triguero et al. (2013) identified the influence of management decisions on eco-innovation and explored the mechanisms that may explain the different types of eco-innovation at the firm-level. Eco-innovation drivers and the study if Venezuela SMEs are environmentally concerned and how much they know about the environmental impact they cause was the objective in the study by Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010). Miranda and Malachias (2012) explored eco-innovation procedures and the impact of sustainability on the business. Suh, Lee and Ha (2005) used eco-efficiency methods in a manufacturing SME to identify and propose innovative environmental friendly processes.

The content analysis on the results of literature studies allowed the identification of convergent aspects regarding the determinants of eco-innovation in manufacturing SMEs. According to Talbot (2005), environmentally proactive SMEs can build the capacity of positively responding to environmental requirements imposed by their customers or regulating agencies as well as contribute to the improvement of environmental performance of the global supply chain consolidating their competitive position. Proactive actions can reduce the risk of being left out of the supply chain in environmentally sensitive markets.

To del Brío and Junquera (2003), in the perspective of public policies, the main factors for successful eco-innovation in SMEs are related to the limited financial resources, the lower SMEs capability to obtain radical innovations, the inability to relate external stakeholders, the lack of regulatory neutrality because large corporations are favoured to the detriment of SMEs, and specific actions (e.g. technological advisory, awareness actions, training programs). With similar results, Triguero et al. (2013) and Bos-Brouwers (2010) also emphasize the importance of environmental policy instruments (e.g. tax, subsidies, voluntary schemes, environmental training programs) and the creation of new organizational capabilities to foster radical eco-innovations.

Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010) conclude that small companies understand environmental regulatory requirements, but they do not perceive the influence of external forces such as customer demand for green products or tax incentives. In the same way, the eco-efficiency practices are not perceived as an incentive to improve competitiveness but to cut down costs and avoid negative effects to the company (e.g. recycling and reutilization of packaging materials). The cut down costs vision is also corroborate in Sánchez-Medina, Corbett and Toledo-López (2011).

The direct participation of SMEs in technological centres running eco-innovation actions works as a catalyst to eco-innovation, mainly where the motivational and economic barriers are detected in the private sector. SMEs must also seek to achieve higher profitability in their R&D projects, exploring the collaboration with universities. However, companies and universities have different R&D objectives (Scarpellini et al., 2012) becoming a barrier for the accomplishment of this collaboration.

Analysing 168 small companies, Sánchez-Medina, Corbett and Toledo-López (2011) concluded that there is a positive relation between eco-innovation and the three dimensions of sustainability (economic, social, and environmental). Moreover, the type of organization and product/process innovation are the factors that best explain the sustainability, whereas the age of the companies is not a significant factor.

To Klewitz, Zeyen and Hansen (2012) proactive actions taken by a public intermediary (e.g. local authorities) are essential and they constitute a key to trigger eco-innovation in SMEs with low absorption capacity. They also require long-term support for eco-innovation from different types of public and private intermediaries with different degrees of support, ranging from customized individual support to more open support, such as cooperation networks. Collaborative networks with research institutes, agencies and universities are essential to trigger all types of eco-innovation in SMEs (Triguero et al., 2013; Gronum, Verreynne and Kastelle, 2012). These initiatives can improve the organizational learning and the absorption capacity. Miranda and Malachias (2012) found advantages in knowledge transfer between suppliers by adoption of sustainable practices in SMEs.

Bos-Brouwers (2010) also concluded that long-term supports as well as long-term management are success factors. Nonetheless, other identified factors that may provide strategic advantages for SMEs over large companies are related to the innovative behaviour of SMEs using networks, the owners' role in conducting innovation and their orientation toward sustainability within the company, and the leadership style of the owner.

Analysing 257 SMEs from diverse industrial sectors from Italy, Mazzanti and Zoboli (2008) identified the following determinants: structural variables of the firm (economies of scale supporting innovative strategies), R&D focused on sustainability; pressure of environmental policies and compliance costs; past performance of the companies (capital expenditure, direct and indirect cost); and the quality or nature of the labour relations.

Investigating 5.222 managers in SMEs of EU Triguero et al. (2013) found that SMEs should see the eco-innovation strategy as a suitable way to increase their potential benefits taking into account the growing environmental consciousness of European consumers. The relationship between supply and demand factors can also affect market relations, pressures for change, corporate image, information flows, and the establishment of cooperation/ collaboration networks. The lack of effectiveness of public subsidies/incentives was another mentioned aspect. Corroborating previous finds, Maçaneiro, Cunha and Balbinot (2013) concluded that factors such as environmental regulation, incentives, reputation effects, top management support, technological expertise and environmental formalization are crucial to the successful adoption of eco-innovation. The synthesis of convergent and more frequently cited eco-innovation determinants in manufacturing SMEs are presented in Table 1.

Table 1: Synthesis of eco-innovation determinants

Determinants	Authors
1. Governmental policy supporting eco-innovation	(1), (2), (5), (4), (7), (8), (11), (13)
2. Regulatory neutrality regarding SMEs and large companies	(1), (11)
3. Availability of resources (people, technology, knowledge)	(1), (2), (4), (5), (6), (7), (8), (10), (11)
4. Scale to support innovative strategies	(1), (4), (6), (8), (9), (11)
5. Perception of the strategic relevance of eco-innovation	(2), (3), (4), (7), (10), (11)
6. Long term strategies as the dominant orientation	(1), (2), (5), (6), (11)
7. Commitment to continually improve and make eco-innovations	(2), (5), (6), (7)
8. Technological advisory oriented to environment	(1), (8), (10), (11)
9. Environmental training, awareness and education	(1), (10), (11)
10. Training programs on cooperation with external stakeholders	(1), (11)
11. Product and process eco-innovation oriented methods	(3), (4), (5), (7), (8), (12)
12. Organizational structure and management support	(3), (5), (6), (9) (11)
13. Supplier and customer relations as source of innovative ideas	(1), (3), (4), (7), (10)
14. R&D department focused on sustainability	(3), (5), (6), (7), (8)
15. Risk management to avoid negative environmental impacts	(6), (7), (10), (11)
16. Cooperation and partnership within supply networks	(2), (5), (7), (9), (11)
17. Process flexibility used to support environmental strategies	(1), (9), (10), (11)
18. Recycling practices and reverse logistics process	(1), (4), (6), (7)
19. Improvements in energy efficiency across the company and in the market	(2), (4), (6)
20. Reputation, brand image and profit margin	(1), (2), (8), (11), (12)
21. Capability for radical improvements on environmental performance	(1), (5), (9)
22. Attractiveness for employees and customers	(1), (6), (7)

23. Capability of organizational learning on eco-innovation issues	(2), (11), (10)

(1) del Brío and Junquera (2003); (2) Klewitz, Zeyen and Hansen (2012); (3) Sánchez-Medina, Corbett and Toledo-López (2011); (4) Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010); (5) Bos-Brouwers (2010); (6) Mazzanti and Zoboli (2008); (7) Talbot (2005); (8) Scarpellini et al. (2012); (9) Miranda and Malachias (2012); (10) Maçaneiro, Cunha and Balbinot (2013); (11) Triguero et al. (2013); (12) Suh, Lee and Ha (2005); (13) Gronum, Verreynne and Kastelle (2012).

Results of the descriptive and content analysis revealed that in-depth interviews of the managers using questionnaires and surveys based on reports and questionnaire are the research procedures more commonly employed to comprehend the determinants in manufacturing SMEs. In addition, due the heterogeneous character of the studies, there is no predominance on a specific sector of manufacturing SMEs (e.g. metal-mechanic, electronic, plastic). This finding corroborates the perspective that studies on eco-innovation in SMEs are recent and offer a number of opportunities for research about specific context. Deeper discussions of these results are presented in the next section.

2.5 Discussion of results

2.5.1 Relationship among the determinants

In this section, we use the citation frequency (Table 2) and a systemic map (Figure 1) to explore the relationship among the determinants of eco-innovation in manufacturing SMEs. Initially, the determinants were classified in seven comprehensive perspectives: external context, internal context, strategies, learning, structure, operations, and results. This analysis allowed the construction of the systemic map, unveiling the paths for eco-innovation.

Table 2
Classification and frequency of citation of determinants for eco-innovation in manufacturing SMEs

Category	Determinants	Frequency
External context	**Governmental policy supporting eco-innovation**	**62%**
External context	Regulatory neutrality regarding SMEs and large companies	15%
Internal context	**Availability of resources (people, technology, knowledge)**	**69%**
Internal context	Scale to support innovative strategies	46%
Strategies	**Perception of the strategic relevance of eco-innovation**	**46%**
Strategies	Long term strategies as the dominant orientation	38%
Strategies	Commitment to continually improve and make eco-innovations	31%

Learning	**Technological advisory oriented to environment**	**31%**
Learning	Environmental training, awareness and education	23%
Learning	Training programs on cooperation with external stakeholders	15%
Structure	**Product and process eco-innovation oriented methods**	**38%**
Structure	**Organizational structure and management support**	**38%**
Structure	**Supplier and customer relations as source of innovative ideas**	**38%**
Structure	**R&D department focused on sustainability**	**38%**
Structure	Risk management to avoid negative environmental impacts	31%
Operations	**Cooperation and partnership within supply networks**	**38%**
Operations	Process flexibility used to support environmental strategies	31%
Operations	Recycling practices and reverse logistics process	31%
Operations	Improvements in energy efficiency across the company and in the	23%
Results	**Reputation, brand image and profit margin**	**38%**
Results	Capability for radical improvements on environmental performance	23%
Results	Attractiveness for employees and customers	23%
Results	Capability of organizational learning on eco-innovation issues	23%

Based on the results presented in Table 2, a model using the systemic map approach was developed to consolidate the findings (Fig.1.). This map allows a better understanding of the relationship among the determinants. Systems thinking is one of main disciplines to be incorporated by organizations and has been used to understand the relationships among variables in different contexts: corporate, urban, regional, economic, political, ecological (Senge, 2006; Checkland, 2000; Helbing, 2013). The modelling process is particularly useful for problem structuring, interdependence identification and knowledge construction (Senge, 2006; Ngana, 2015; Ackoff, 1981; Sterman, 2000; Crescitelli and Figueiredo, 2009). It provides a valuable means for managing complexity (Helbing, 2013; Ackermann and Eden, 2011). The systemic thinking has its own language to show the direction of influence between variables, dependent and independent, cause and effect and the direct or inverse relations. We choose a simple map emphasizing the direct effect of one dimension over the others. Full links between variables represent direct relationships: if a variable increases or decreases, the other does the same (Senge et al., 2014).

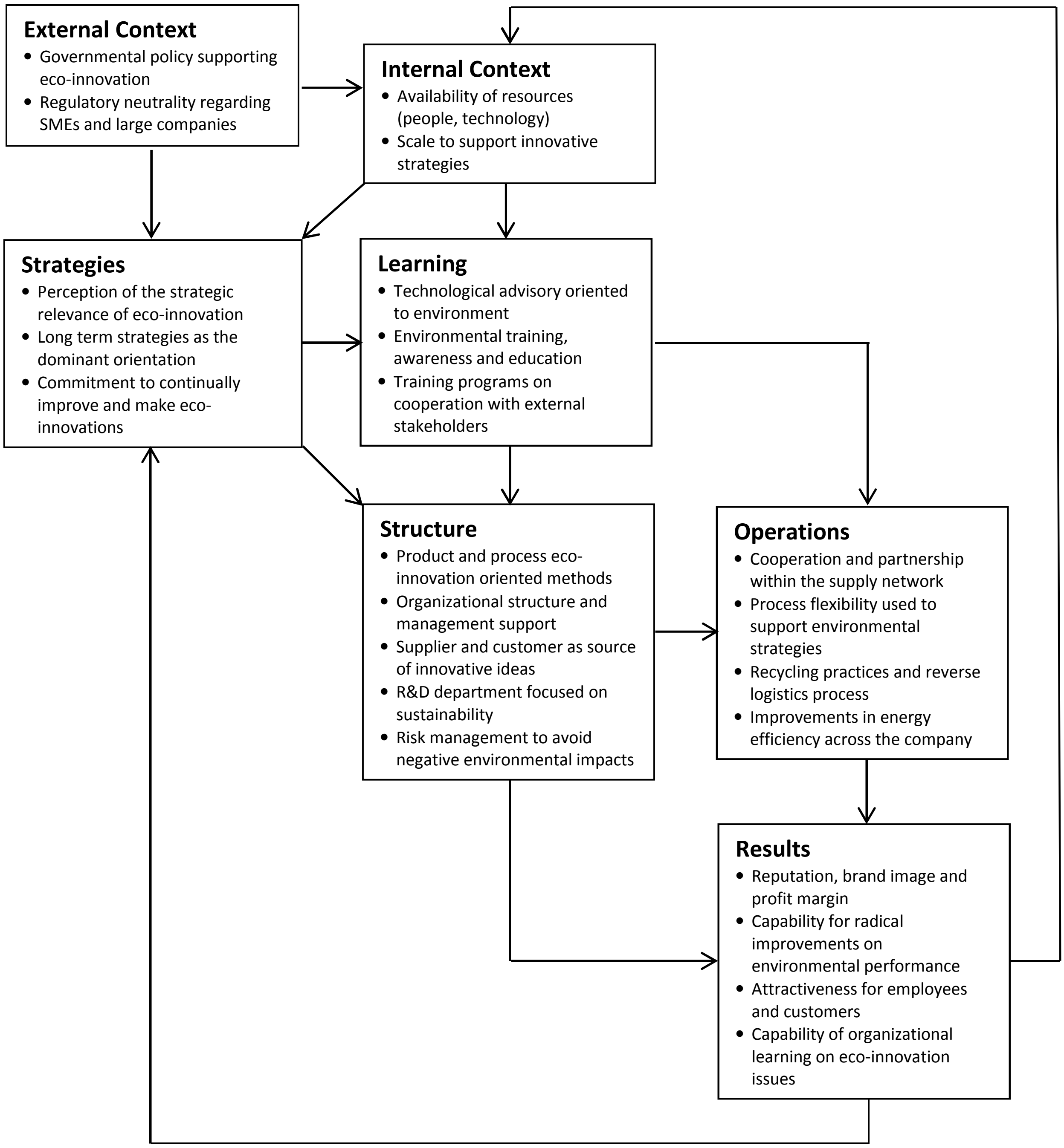

Fig. 1. Systemic relationship among the determinants for eco-innovation in manufacturing SMEs.

The analysis of the model presented in Figure 1 allows the identification of some critical perspectives and determinants considering the manufacturing SMEs context. The external context (determinants 1 and 2) and the internal context (determinants 3 and 4) influence and guide the definition of strategies (determinants 5 to 7). Strategies, in turn, conduct to improvements on learning (determinants 8 to 10) and structural (determinants 11 to 15) aspects. The determinants classified in learning and structure facilitate operations (determinants 16 to 19), while structure and operations constitute the direct means for producing positive results in manufacturing SMEs (determinants 20 to 23). These results cause minor changes in strategies (while they are being monitored) and, also, major changes in the internal context, which will influence the next strategic cycle, closing the feedback loops.

The detailed analysis of the systemic relationship among the determinants allows some further discussion focusing on the most cited item of each class, which are marked in bold in Table 2. Starting from the internal context perspective, the availability of resources (e.g. people, technology and knowhow) was the most cited item, standing out as a critical determinant. This is so because eco-innovation demands some degree of investments, expressed as qualified people or acquisition of technology or knowledge. However, the lack of resources is the usual scenario for manufacturing SMEs (Mazzanti and Zoboli, 2008; Triguero et al., 2013) restraining these investments.

Considering the external context perspective, governmental policy supporting eco-innovation is emphasized as the critical determinant (del Brío and Junquera, 2003; Klewitz, Zeyen and Hansen, 2012; Gronum, Verreynne and Kastelle, 2012). Clearly, some governmental support expressed as protecting laws or subsides for innovation and environmental actions constitute strong elements to mitigate the usual lack of resources that characterizes manufacturing SMEs.

Regarding the strategic perspective, the perception of the relevance of eco-innovation (for customer, for society, for company) appears as the critical – most cited – determinant. Top management perception is mandatory to support long-term strategies and actions demanded for eco-innovation (Maçaneiro, Cunha and Balbinot, 2013). This is so because innovation deserves some time to succeed and bring results for the company (Klewitz, Zeyen and Hansen, 2012).

Technological advisory oriented to environment stands out as the most cited determinant related to the learning perspective. This is a topic demanding further research, since we would expect that training, awareness and education would be highlighted in the literature (del Brío and Junquera, 2003; Triguero et al., 2013). Nevertheless, the reason for the emphasis on technologic advisory may be related to the lack of technology expertise that characterizes manufacturing SMEs, compared to large manufacturing companies (Scarpellini et al., 2012; del Brío and Junquera, 2003).

From the structural perspective, four determinants presented the same most cited frequency: (i) Product and process eco-innovation oriented methods, (ii) Organizational structure and management support, (iii) Supplier and customer relations as source of innovative ideas and (iv) R&D department focused on sustainability. This result corroborates the idea that eco-innovation success demands an adequate structure (Bos-Brouwers, 2010; Mazzanti and Zoboli, 2008; del Río, Carrillo-Hermosilla and Könnölä, 2010). Since the structure of manufacturing SMEs (regarding methods, management support and R&D department, i.e) is usually weak (compared to large companies), this may be a major constraint to be overcome by strategies and learning.

Considering the operations perspective, cooperation and partnership within supply networks was the most cited item. This is a critical determinant due to two aspects: (i) survival of manufacturing SMEs depends on the ability to cope with supply chain demands (Gronum, Verreynne and Kastelle, 2012; Triguero et al., 2013; Bos-Brouwers, 2010) and (ii) eco-innovation is facilitated by partnerships (e.g. direct participation of technological centres on eco-innovation, collaboration with universities and research agencies), which may boost ideas and forward projects (Scarpellini et al., 2012).

Reputation, brand image and profit margin were emphasized as the critical determinant of the Results perspective (del Brío and Junquera, 2003; Klewitz, Zeyen and Hansen, 2012; Scarpellini et al., 2012; Triguero et al., 2013). This occurs because tangible results, characterized as market image and profit margin is essential to feedback eco-innovation. Without concrete results in a reasonable timeframe, (i) the perception of the relevance of eco-innovation will fade way, and (ii) the usual low availability of resources will persist, inhibiting new projects. In short, the findings in our research shows that the model organizes clearly the direct relationships between the determinants and main perspectives found in the literature review. Furthermore, it was possible to identify critical determinants and alternative strategies to decision makers and policy makers in manufacturing SMEs context.

2.5.2 Analysis of review protocol

As proposed in our method section, the literature review protocols suggested by Liberati et al. (2009) were applied to verify the validity of the findings. Among other analysis alternatives, Liberati et al. (2009) suggest the following five criteria. First, the title of the article must identify whether it is a systematic review, meta-analysis or both. In this case, our title characterizes the study as a systematic review. Second, it is suggested to include the context, objectives, source of data, eligibility criteria of the studies, evaluation of the studies, synthesis methods, limitations and conclusions. To meet this requirement, these aspects were detailed in the method section. Third, the introduction should present the research questions and the justification of the study. These requirements were achieved discussing the literature gaps regarding eco-innovation in manufacturing SMEs.

Fourth, the eligibility criteria for articles, sources of information, search strategy and selection process, risk of bias, synthesis of the outcomes and additional analyses should be presented. All these criteria were contemplated in our methods and discussion sections. Tables 1 and 2 and Figure 1 shows the analysis and synthesis of the data and objectively present the main elements and findings of our study.

Fifth, the following criteria are suggested for the discussion section: number of studies included and evaluated, individual outcomes of the studies, synthesis of the outcomes and additional analyses, synthesis of the conclusions, discussion of the limitations and overall interpretations of the study. The steps described in the method section presented the number of studies included and evaluated. Tables 1 and 2 describe the synthesis of the individual outcomes and as an additional analysis a systemic map was developed to explore the results. In the conclusion section, the conclusions, limitations and overall interpretations of the study were placed. Thus, overall, the systematic review requirements were achieved in accordance with the protocol of Liberati et al. (2009).

In short, it is possible to say that our research has met the objectives originally expressed as the research question. As the main contribution, the results of our study can be used by governmental policy makers to create specific strategies to improve the adoption of eco-innovation in manufacturing SMEs. Moreover, industrial professionals can use the results of our study to focus resources (money, people and management time) to boost the correct determinants, bearing in mind that the availability of resources in manufactory SMEs are generally scarce.

2.6 Concluding Remarks

Studies like del Río, Peñascoa and Romero-Jordán (2016), Klewitz and Hansen (2014), Cai and Zhou (2014) and Triguero et al. (2013) claim the need of news researches in eco-innovation drivers to provide a differentiated look at SMEs according the type of industry. Our paper contributes to this by discussing eco-innovation in the specific context of manufacturing SMEs.

A systematic review of literature comprising the last twenty-four years was carried out to identify the determinants for eco-innovation in manufacturing SMEs. The research effort was restricted to understanding specific elements that may influence the success of eco-innovation in manufacturing SMEs. The review of literature on eco-innovation allowed the identification of a list of determinants, the outline of the relationship among the determinants, and the identification of the critical determinants. The results contribute to academic, policy makers and professional through the indication of twenty-three eco-innovations determinants for manufacturing SMEs, assigning the critical determinants and discussing the relationship among them.

The determinants were classified in seven categories: External context, Internal context, Strategies, Learning, Structure, Operations, and Results. The identified critical determinants were: Governmental policy supporting eco-innovation; Availability of resources (people, technology, knowledge); Perception of the strategic relevance of eco-innovation; Technological advisory oriented to environment; Product and process eco-innovation oriented methods; Organizational structure and management support; Supplier and customer relations as source of innovative ideas; R&D department focused on sustainability; Cooperation and partnership within supply networks; and Reputation, brand image and profit margin.

Future studies contemplating: (i) best practices for eco-innovation in manufacturing SMEs and (ii) systems for effective cooperation in eco-innovation are recommended. Other relevant research opportunity is the identification of successful policy instruments already adopted in different countries to support eco-innovation in manufacturing SMEs.

Our study also identified some strategic alternatives to mitigate the impact of certain determinants in manufacturing SMEs that deserves deeper studies. Some of these alternatives are: (i) the adoption of a proactive behaviour to co-create value developing eco-innovations in partnership with customers, (ii) the application of the

PSS perspective on eco-innovation (Ceschin, 2013; Bertoni et al., 2015), (iii) the use for eco-innovation of specific tools consolidate in previous studies such as LCA, TRIZ, Eco-design, Biomimetic (Chen, 2015; Fresner et al., 2010; Recchioni et al., 2007), (iv) the establishment of partnerships within the supply chain oriented to eco-innovation and (v) the establishment of a culture favourable for eco-innovation.

Concerning limitations of this research, it is necessary to point out that results and analyses are directly related to the search criteria adopted. In this sense, some databases and dissertations and theses were not included in our research. Another limitation is the timeframe. The research interval could be expanded. These points are also opportunities for new investigations.

The results corroborate that the discussion on eco-innovation, especially in manufacturing SMEs, is in early development stage. In this sense, due to the lack of previous studies on this topic, the performed analysis was not categorized by country, maturity of eco-innovation culture, type of manufactured product (e.g. plastic, paper, metal), sector (e.g. metal-mechanic, automotive, electronic) or even by manufacturing strategy (e.g. make to order, make to stock, engineer to order). In the near future, as the number of published studies on eco-innovation increases, analyses comprising such detailed categorization will be possible. Finally, the last suggestion for further research along this subject would be the validation of the determinants identified in this systematic review through empirical researches. These are important opportunities to advance the academic and practical perspective of this emergent research topic.

Acknowledgments

This research was supported by Brazilian Council for Scientific and Technological Development (CAPES/CNPq) under grant number 00230916 and by Portuguese Foundation for Science and Technology (FCT).

REFERENCES

Ackermann, F., Eden. C. 2011. Strategic management of stakeholders: Theory and practice. Long Range Planning 44, 179–196.

Ackoff, R. 1981. The art and science of mess management. Interfaces 11, 20–26.

Andersen, M. M. 2008. Eco-innovation – towards a taxonomy and a theory. DRUID Conference Entrepreneurship and Innovation: Organizations, Institutions, Systems and Regions, June, Copenhagen.

Arundel A., Kemp, R. Measuring eco-innovation. UNU-MERIT. Working Paper Series, 2009. Avaible in: http://www.merit.unu.edu/publications/wppdf/2009/wp2009-017.pdf

Aykol, B., Leonidou, C. L. 2014. Researching the Green Practices of Smaller Service Firms: A Theoretical, Methodological, and Empirical Assessment. Journal of Small Business Management, 53 (4): 1264–1288.

Bertoni, A. et al. 2015. Expanding Value Driven Design to meet Lean Product Service Development. Procedia CIRP 30, 197–202.

Blackburn, W. R. 2008. The Sustainability Handbook: The Complete Management Guide To Achieving Social, Economic and Environmental Responsibility. Environmental Law Institute, (1th ed.).

Blackburn, W. R. 2007. The Sustainability Handbook: The Complete Management Guide to Achieving Social, Economic and Environmental Responsibility. Washington, DC: ELI Press.

Block, J. H., Fisch, C. O., Hahn, A., Sandner, P. G. 2015. Why do SMEs file trademarks? Insights from firms in innovative industries, Research Policy 44, 1915-1930.

Boly, V., Morel, L., N'Doli, G. A., Camargo, M. 2014. Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation, Research Policy 43, 608-622.

Bos-Brouwers, H. E. J. 2010. Corporate Sustainability and Innovation in SMEs: Evidence of Themes and Activities in Practice. Business Strategy and the Environment. 19 417–435.

Cai, Wu-gan., Zhou, Xiao-liang. 2014. On the drivers of eco-innovation: empirical evidence from China. Journal of Cleaner Production 79, 239-248.

Carrillo-Hermosilla et al., 2009. Eco-innovation: when sustainability and competitiveness shake hands. New York: Palgrave Macmillan (1th ed.).

Ceschin, F. 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production 45, 74-88.

Checkland, P.2000. Soft systems methodology in action: a 30-year retrospective. Systems Research and Behavioral Science Syst. Res. 17, 11–58.

Chen, Wang-Chih., Chen, J.L. Eco-innovation by Integrating Biomimetic Design and ARIZ. 2014. Procedia CIRP 15, 401–406.

Conforto, E. C., Amaral, D. C., da Silva, S. L. 2011. Roadmap for systematic literature review: application in product development and project management. 8th Brazilian Congress of Management and Product Development, Porto Alegre, Brazil.

Costantini, V. et al. 2015. Demand-pull and technology-push public support for eco-innovation: The case of the biofuels sector. Research Policy 44, 577-595.

Crescitelli, E., Figueiredo, J. B. 2009. Brand equity evolution: a system dynamics model. BAR - Brazilian Administration Review, 6 (2), 101-117.

Cuerva, M.C., Triguero-Cano, A. Corcoles, D. 2014. Drivers of green and non-greeninnovation: empirical evidence in Low-TechSMEs. Journal of Cleaner Production, 68 (1), 104-113.

del Brío,J. Á., Junquera, B. 2003. A review of the literature on environmental innovation management in SMEs: implications for public policies, Technovation 23, 939–948.

del Río, P., Peñascoa, C., Romero-Jordán, D. 2016. What drives eco-innovators? A critical review of the empirical literature based on econometric methods. Journal of Cleaner Production, 112 (4), 2158–2170.

del Río, P., Carrillo-Hermosilla, J., Könnölä, T. 2010. Policy Strategies to Promote Eco-Innovation: An Integrated Framework. Journal of Industrial Ecology, 14 (4), 541–557.

Doh, S., Kim, B. 2014. Government support for SME innovations in the regional industries: The case of government financial support program in South Korea. Research Policy 43, 1557-1569.

Dyba, T.; Dingsoyr, T. 2008. Empirical studies of agile software development: a systematic review. Information and Software Technology 50, 833-859.

Fernández-Viñé, M. B., Gómez-Navarro, T., Capuz-Rizo, S. F. 2010. Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives. Journal of Cleaner Production, 18, 736–746.

Foxon, T., Andersen, M. M. 2009. The greening of innovation systems for eco–innovation – towards an evolutionary climate mitigation policy. Proceedings of the DRUID Summer Conference – Innovation, Strategy and Knowledge, Copenhagen. Hovedstaden, DK, 27.

Fresner, J., Jantschgi, J., Birkel, S., Barnthaler, J., Krenn, C. 2010. The theory of inventive problem solving (TRIZ) as option generation tool within cleaner production projects. Journal of Cleaner Production 18, 128–136.

Fussler, C., James, P. 1996. Driving Eco-Innovation: A Breakthrough Discipline for Innovation and Sustainability, Pitman Publishing: London, 364 p.

Gronum, S., Verreynne, M. L., Kastelle, T. 2012. The Role of Networks in Small and Medium-Sized Enterprise Innovation and Firm Performance. Journal of Small Business Management, 50 (2): 257–282.

Helbing, D. 2013. Globally networked risks and how to respond. Nature 497, 51–59.

Hottenrott, H., Lopes-Bento, C. 2014. R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes, Research Policy 43, 1055-1066.

James, P. 1997. The Sustainability Circle: a new tool for product development and design. Journal of Sustainable Product Design 2, 52-57.

Kemp, R., Foxon, T. J. Typology of Eco-Innovation. In: MEI project: measuring Eco-Inovation. European Commission, ago. 2007. Available in:

http://www.merit.unu.edu/MEI/deliverables/MEI%20D2%20Typology%20of%20eco-innovation.pdf.

Kemp, R.; Pearson, P. 2008. Final report MEI project about measuring eco-innovation: Deliverable 15 of MEI project (D15). Available in: http://www.merit.unu.edu/MEI/

Klewitz, J., Zeyen, A., Hansen, E. G. 2012. Intermediaries driving eco-innovation in SMEs: a qualitative investigation, European Journal of Innovation Management 15 (4), 442-467.

Klewitz, J., Hansen, E. G. 2014. Sustainability-oriented innovation of SMEs: A systematic review. Journal of Cleaner Production 65, 57-75.

Kolltveit, B., Karlsen, J., Gronhaug, K. 2007. Perspectives on project management. International Journal of Project Management 25 (1), 3-9.

Lee, N., Sameen, H., Cowling, M. 2015. Access to finance for innovative SMEs since the financial crisis. Research Policy 44, 370-380.

Levidowa, L. et al. 2015. Process eco-innovation: assessing meso-level eco-efficiency in industrial water-service systems. In Press. Journal of Cleaner Production.

Liberati, A. et al. 2009. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. PLoS Medicine, 6 (7), 1-27.

Little, A.D. 2006. The innovation high ground: Winning tomorrow's customers using sustainability-driven innovation. Strategic Direction, 22(1), 35-37.

Levy, Y., Ellis, T.J. 2006. A system approach to conduct an effective literature review in support of information systems research. Informing Science Journal 9, 181-212.

Mazzanti, M., Zobloi, R. 2008. Environmental Innovations, SME Strategies and Policy Induced Effects:Evidence for a District-Based Local System in Northern Italy. The Icfai Journal of Environmental Economics 6 (1), 7-34.

Maçaneiro, M.B., Cunha, S. K., Balbinot, Z. 2013. Drivers of the Adoption of Eco-Innovations in the Pulp, Paper, and Paper Products Industry in Brazil. Latin American Business Review. 14 (3-4), 179-208.

McGuirk, H., Lenihan, H.,Hart, M. 2015. Measuring the impact of innovative human capital on small firms' propensity to innovate, Research Policy 44, 965-976.

Mendonça, A. T. B. B., Cherobim, A. P. M. S., Cunha, S. K. 2012. Sectoral systems of Sustainable Innovations: analysis of categories, types and measurement measures. XXVII Technological Innovation Management Symposium, Anpad, Salvador, Brazil.

Miranda, L. M. B. B., Malachias, C. S. Análise da inovação e sustentabilidade: estudo de caso de uma madeireira brasileira. Proceedings: Simpoi, 2012.

Navas, H.V.G. In: Garrido SA, Brandenburg M, Carvalho H, Cruz-Machado V. Eco-Innovation and the Development of Business Models. Ed. Springer International Publishing. 2014, 314 p..

Ngana, J. P. 2015. Management with a Frame of Mind for Systemic Thinking: A Conceptual Condition Setting Tool. Systems Research and Behavioral Science 32 (2), pp. 175–182.

OECD.Policy Brief: Sustainable Manufacturing and Eco-innovation: Towards a Green Economy. June 2009a.Available in: http://www.oecd.org/dataoecd/34/27/42944011.pdf

OECD. Sustainable manufacturing and eco-innovation: Framework, Practices and Measurement. Synthesis Report Paris: OECD, 2009b. Available in: http://www.oecd.org/dataoecd/15/58/43423689.pdf

Padula et al. 2015.SMEs inventive performance and profitability in the markets for technology. Technovation, In Press.

Przychodzen, J. W. 2015. Relationships between eco-innovation and financial performance – evidence from publicly traded companies in Poland and Hungary. Journal of Cleaner Production 90 (1), 253-263.

Recchioni, M., Mandorli, F., Germani, M., Faraldi, P., Polverini, D. 2007. Life-Cycle Assessment Simplification for Modular Products. Proceedings of the 14th CIRP Conference on Life Cycle Engineering, Tokyo, Japan.

Reid, A., Miedzinski, M. Eco-Innovation, Final Report for Sectoral Innovation Watch. L Brussels: Technopolis Group, 2008. Available in: http://www.technopolis-group.com/resources/downloads/661_report_final.pdf.

Rennings, K. 2000. Redefining innovation-eco-innovation research and the contribution from ecological economics. Ecological Economics, 32(2), 319-332.

Sánches-Medina, P. S., Corbett, J., Toledo-Lopez, A. 2011. Environmental Innovation and Sustainability in Small Handicraft Businesses in Mexico, Sustainability 3, 984-1002.

Scarpellini, S. et al. 2012. R&D and eco-innovation: opportunities for closer collaboration between universities and companies through technology centers. Clean Technologies and Environmental Policy 14 (6), 1047-1058.

Schumpeter, J. A. Das Wesen und der Hauptinhalt der Nationaloekonomie, 1908.

Schumpeter, J. A. Die Theorie der Wirschaftlichen Entwicklung, 1911.

Schumpeter, J. A. Capitalism, socialism and democracy, 1942.

Senge, P. 2006. The fifth discipline: The art and practice of the learning organization. New York: Doubleday. 445 pp.

Senge, P., Kleiner, A., Roberts, C., Ross, R., Smith, B. 2014. The fifth discipline field book: strategies and tools for building a learning organization. Crown Business, New York.

Simboli, A., Taddeo, R , Morgante, A. 2014. Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors. Journal of Cleaner Production 66, 372-383.

Sterman, J. 2000. Business dynamics: Systems thinking and modeling for a complex world. Irwin, McGraw-Hill, Chicago.

Suh, S.,Lee, M. K., Ha, S. 2005. Eco-efficiency for Pollution Prevention in Small to Medium-Sized Enterprises: A Case from South Korea. Journal of Industrial Ecology 9 (4), 223–240.

Talbot, S. 2005. Ecodesign practices in industry: an appraisal of product life cycle design initiatives in SMEs. Engineering Management Conference.

Tranfield, D., Denyer, D., Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Triguero, A., Moreno-Mondejar, L., Davia, M. A. 2004. The influence of energy prices on adoption of clean technologies and recycling: Evidence from European SMEs. Energy Economics 46, 246-257.

Triguero, A., Moreno-Mond, L., Davia, M.A. 2013. Drivers of different types of eco-innovation in European SMEs. Ecological Economics 92, 25-33.

Webster, J., Wartson, J.T. 2002. Analyzing the past to prepare for the future: writing a literature review. MIS Quarterly & The Society for Information Management 26 (2), 13-23.

3 Artigo 2: Eco-innovation determinants in Brazilian manufacturing SMEs: literature review and challenges

Abstract

The debate on eco-innovation is a recent and emergent topic between practitioners and in the academy. Especially in on developing economies, such as in Brazil, this topic is very incipient mainly in Small and Medium-Sized Enterprises (SMEs) context. Hence, the purpose of this study is to identify what are the determinants factors for the successful adoption of eco-innovation in Brazilian SMEs. The research method adopted initially the literature review about eco-innovation in SMEs covering Web of Science, Scopus, and Ebsco databases to identify the consolidated eco-innovation determinants cited by literature. Next, a questionnaire followed by content analysis of results was conducted with Brazilian experts in eco-innovation to identify the determinants specific to Brazilian SMEs economic context. Findings permitted identify several similarities/differences and intersections/overlaps in this analyses. As a result, a list of primary sixteen determinants was obtained to Brazilian SMEs. Results also demonstrated that the eco-innovation in SMEs may be enable breaking away from the immediatist culture, by participation of SMEs in cooperation networks, considering the regulations affecting the sector where the SME operates and the applicable legislation, investing in R&D of innovative technologies in conjunction with external agents, qualified professionals to plan for and implement eco-innovation and reinforcing the financial condition of the SMEs. The practical contribution of this study is consolidated a comprehensive framework of eco-innovation to Brazilian SMEs providing important insights and challenges to academics, policy makers, and practitioners to improve the diffusion of eco-innovative practices.

Keywords: Eco-innovation. Innovation. Determinants. Literature review. Qualitative analysis. Small and Medium Enterprise.

3.1 Introduction

Currently, the sustainable development and technological innovation are recurring themes in society, academic and in business environments. The first studies of innovation date back to the propositions made by Schumpeter. Innovation was first categorized by Schumpeter in the book “The Theory of Economic Development” published in 1911 in Austria. Blackburn (2007; 2008) claims that the definition of environmental sustainability is not yet fully clear since there is still some confusion in business circles. Blackburn (2007) and Carrilo-Hermosilla et al. (2009) discuss some aspects related to the history of sustainability, and refer to the 1972 United Nations Conference on Human Development in Stockholm as the time when the term sustainability first surfaced, a fact that Mendonça et al. (2012) corroborate. Regarding the discussion about integrating innovation and sustainability, the first studies published in the literature according to Maçaneiro and Cunha (2012) were carried out by Fussler and James (1996), James (1997) and Rennings (2000). Fussler and James (1996) are supposed to have coined the term “eco-innovation” in a book titled “Driving Eco-Innovation: A Breakthrough Discipline for Innovation and Sustainability."

If, on the one hand, the theme of innovation has been strictly connected with economic concerns, such as competitiveness, demand and investment, on the other hand, the environmental area has been hard put to incorporating the technological innovation processes. Compared with publications in classical innovation, there are currently only a few numbers of studies about the management of technological eco-innovation and its processes (Ozaki et al., 2013; Klewitz and Hansen 2014). This debate has been widely discussed in the context of large companies, mainly in industrial and technological sectors. However, the discussion of the impacts in SME is still incipient and inconclusive.

Moreover, in the field of environmental sustainability, there are studies and mainly a few effective actions identified about the integration and comprehension of these two themes specific to SMEs context (Klewitz and Hansen, 2014; Sabadie, 2014; Borghesi, 2015). Nevertheless, on the whole, the debate of innovation in SMEs is focused on other topics. Such for example, open innovation (Brunswicker and Vanhaverbeke, 2015; Wynarczyk et al., 2013), the product innovation (Massis et al., 2015; Maes and Sels, 2014), SMEs networks (Gronum et al., 2012), in innovation process (Love and Roper, 2015) or internationalization (Raymond and Pierre, 2013) and others.

Therefore, in this sense, considering that the integration of innovation and sustainability is relatively recent in literature, is possible conclude that even more immature is the discussion about eco-innovation particularly in the SMEs context (Klewitz and Hansen, 2014; Rashid et al., 2015; del Río et al., 2015) and mainly in emergent or income economies such as the Brazil. Recent studies also corroborated this assumption (Govindan et al., 2016).

Hence, more investigations aiming to advance in the diffusion of eco-innovations in SMEs are necessary (Klewitz and Hansen, 2014). To achieve this goal, systematic review literature on eco-innovation of SMEs are necessary for several reasons (Klewitz and Hansen, 2014). First, SMEs are considered a type of enterprise internationally relevant to the economy of nations. According to OECD, SMEs make out between 96% and 99% of the total number of companies from EU. Second, SMEs as a group contribute to a significant share of overall pollution. Third, SMEs are not simply smaller versions of their larger counterparts. Fourth, SMEs' peculiarities imply that they will innovate differently for sustainability. Fifth, the literature highlighting SMEs' disadvantages (e.g. resource constraints, lack of formalized planning) which may prevent them from engaging proactively in the innovation process showing reactive behavior toward environmental and social issues.

In this direction, if on the one hand, the debate and research on eco-innovation is more frequent in the international context, on the contrary, in Brazil this topic is very incipient, and just a few scarce studies have been developed in recent past years. In fact, concerning Brazilian SMEs, this discussion is in a more immature stage yet. Therefore, this topic needs to be better understood in the landscape of Brazilian economy. Thus a suitable strategy for obtain success to comprehend this phenomenon is to analyze which are the determinants for eco-innovation in Brazilian SMEs and also whether they are similar or not to results of empirical results available on literature.

In short, based on the gaps in the literature previously discussed, the research question that drives this study is: what are the determining factors to implementing of eco-innovation practices in Brazilian SMEs? The research process adopted started with a review of the existing literature international on eco-innovation in the main scientific databases to identify and analyze these determinants. Next, a semi-structured questionnaire was applied with Brazilian experts to identify which are the determinants to eco-innovation to the Brazilian SMEs. Lastly, the results of the literature review were compared against the answers of Brazilian experts aiming to identify similarities/differences and intersections/overlaps. The main contribution of this study contributes to future research on the implementation of eco-innovation practices in SMEs in emergent countries such as the Brazil. The originality of our study also may contribute to providing a common identity for the scientific and industrial community interesting in the eco-innovation field. In our opinion, these research lines will contribute to a better understanding and clearness of the scope of eco-innovation in emergent economies.

The remain of the paper' structure is organized as follow. After present the research problem and justification in the Introduction, section two shows the theoretical framework of eco-innovation definitions and the eco-innovation determinant extracted from the Scopus, Web of Science and Ebsco databases. The next section Research Method details the methodology procedures to collect and analysis the data. In the section Results are presented the qualitative analyses results emphasizing the Brazilian specialists' responses. The Discussion of results is made in section five. The analysis of results was made comparing the determinants found in the literature with the factors highlighted by the specialists. Moreover, is made the identification of similarities/differences and intersections/overlaps about the results. Section six shows the conclusions and key research directions to this research field.

3.2 Theoretical Background

3.2.1 Defining eco-innovation

Bos-Brouwers (2010) affirm that the most available research on innovation and sustainability applies to large companies, whereas the innovation process for SMEs is different. Is possible state that the most common difference between large companies and SMEs is the number of employees. However, others characteristics can be summarized (Bos-Brouwers, 2010):

Table 1 - SMEs versus Large companies

SME	Large companies
Dominant role of the entrepreneur/owner	Delegated management control between board of directors and shareholders
Resource poverty (capital, time, knowledge and skilled personnel)	Economy of scale, resource abundance
Flexible organization capacities	Bureaucratic rigidity
Focus on short term	Focus on mid to long term
Strong local/regional focus and customer needs orientation	Strong (inter)national focus and looser ties with customers
Low degree of formalization	High degree of formalization

Maçaneiro and Cunha (2010; 2012) demonstrate that eco-innovation differs from the concept of innovation as it relates to the reduction of environmental impacts. As such, eco-innovation consists in changes to the environmental performance and improvements based on the dynamics of ecologizing products, processes, business strategies, markets, technologies, and systems of innovation. The authors make such differentiation between several Eco-innovation definitions (Table 2).

Table 2 - Definitions of eco-innovation

Author	Eco-innovation definitions
James (1997)	Eco-innovation is considered a new product or process that adds value to the business and to the customer, significantly decreasing the environmental impact.
Rennings(2000), Kemp & Foxon (2007), Arundel & Kemp (2009)	It is the productions, application or exploration of goods, services, production process, organizational or management structure or method of business that is new to the company or to the user. The results are the reduction of environmental impact, less pollution or negative impacts from the utilization of resources, compared with corresponding alternatives.
Andersen (2008), Foxon & Andersen (2009)	It is defined as the innovation that is capable of attracting green income in the market, reducing the net environmental impact, and creating value for the organizations.
Reid and Miedzinski (2008)	It is the creation of new and competitive efforts of products, processes, systems, services and procedures conceived to meet the human needs and to provide a better quality of life for everyone, with as little as possible utilization of the life cycle of natural resources and release of toxic substances.
Kemp and Pearson (2008)	It is the production, assimilation or exploration of a product, production process, service or method of management or business that is new to the organization (developing or adopting it) which results, over its life cycle, in the reduction of environmental risks, pollution and other negative impacts from the use of resources, including power, compared with corresponding alternatives.
OECD (2009a)	It represents an innovation that brings about a reduction of the environmental impact whether such effect is intentional or not.

There is some variation between the concepts proposed from 1997 through 2009. In a comparison between the definition of James (1997) and the definition of OECD (2009a) in Oslo Manual, the idea of an effective reduction of environmental impact is highlighted. Barbieri et al. (2010) corroborate such statement as it puts forward some definitions and expresses that the concept of eco-innovation is not only about reducing negative impacts; it includes the achievement of net benefits as well. The condition that is emphasized, comparison of pertinent alternatives, is essential to the concept of sustainable innovation since the desired benefits must be significant or non-negligible in the three dimension of sustainability (social, economic and environmental). Foxon and Andersen (2009) point out that eco-innovation practices are more than the adoption of low carbon technologies; they require learning new things, the creation of new knowledge, values, a search for rules and capabilities in addition to the creative destruction of old practices and capabilities. According to Sehnem et al. (2016), the typology of eco-innovation categories often adopted in theoretical and empirical studies is classified in six categories: Product, Process, Organizational, Marketing, Social, and System eco-innovations.

3.2.1.1 Product Eco-innovation

Product eco-innovation includes goods and services. Eco-innovative properties are produced so that the overall impact on the environment is minimized, and eco-design is a keyword in this area. The future of product design will take into account resource constraints with a higher priority than is happening today. Designing a product in a way that leads to reduced environmental impact and lower resource usage during operation and which allows recovery options such as repair, reuse or recycling should become the main business strategy, not only to reduce costs but also to improve the security of supply and resilience of markets. Eco-innovative services include green financial products (such as credits for renewable energy, green credit card, etc.), environmental services (including waste management) and less service intensive resources (e.g. car sharing).

3.2.1.2 Process Eco-innovation

Eco-innovative processes reduce the use of materials, provide the lowest risk and result in cost savings. Examples include substitution of harmful inputs during the production process (for example, the replacement of toxic substances); optimization of the production process (for example, to improve energy efficiency); and reduction of the negative impact of production output (such as emissions). In addition, the reduction of inputs- material inputs into production processes and consumption - can also be captured by the process of eco-innovation. Common terms related to ecological process innovations include cleaner production, zero emissions, zero waste and material efficiency.

3.2.1.3 Organizational Eco-innovation

Organizational eco-innovation is the introduction of organizational methods and management systems to deal with environmental issues in production and products. These organizational changes are the socio-economic dimension of the innovation process and are especially closely linked to learning and education. Such eco-innovation includes pollution prevention schemes, environmental management and audit systems, and management of the supply chain (business cooperation to strengthen the material bonds and to avoid environmental damage throughout the value chain). As such, organizational eco-innovation can also include an investigation into the various collaborative organizational forms and possible eco-innovative quality, which can range from business networks and clusters to advanced industrial symbiosis solutions.

3.2.1.4 Marketing Eco-innovation

Eco-innovation marketing involves changes in product design or packaging, product placement, promotion of products or prices. It looks at how marketing techniques can be used to drive people to buy, use or implement eco-innovations. In marketing, the brand (a collection of symbols, experiences, and associations connected with a product or service by potential customers) is the key to understanding the process of marketing products and services. While green branding is important, in practice it is not the function or way to sell eco-innovations. Labeling is also an aspect of eco-marketing innovation, namely eco-labeling.

3.2.1.5 Social Eco-innovation

Social eco-innovation considers the essential human element in any discussion about resource consumption. This includes behavioral dimensions based on the market and change of lifestyle and the resulting demand for goods and green services. Some companies are experimenting directly with stakeholders, developing the functionality of new goods according to their interests, and thus minimizing the risk of use of luxury goods resources. Another important aspect is the sharing of the product, which can lead to an absolute reduction in the use of materials without diminishing the quality of services provided to users. The social dimension also involves the creative potential of society with examples of innovative concepts of green living.

3.2.1.6 System Eco-innovation

A series of connected innovations improve or create entirely new systems with specific functions with a reduced overall environmental impact. A key feature of a system of innovation is that it is a set of changes implemented by the project. For example, a system of eco-innovations related to a residence involves not just insulation of windows or use of a better heating system: it aims to innovate the overall design to improve functionality. The idea of green cities is another example of an innovation system, where innovation and planning efforts lead to a combination of changes to improve the functioning of the city and facilitate the greenest city life. This includes, for example, new concepts of mobility considering not only the traditional public transport services (e.g. bus), but also shared bicycle systems (and related infrastructure such as bike stations), as well as planning to reduce the need to travel (which requires that supermarkets, nurseries, etc. are incorporated into new developments).

3.2.2 Eco-innovation determinants in SMEs

This section shows the synthesis of systematic review detailed in next section of Research Method, highlighting the determinants to eco-innovation described pointed in the select papers. A well-cited publication in this field is the study of Brío and Junquera (2003) that explored the implications for public policies to leverage sustainable innovations in SMEs. Investigating of the barriers to eco-innovation and driving aspects of eco-innovation in Germany SMEs that participating of innovation network *Ecoprofit*, Klewitz, Zeyen and Hansen (2012) conclude that: (i) the main eco-innovation driving factors are cost-efficiency, proactive contact by external initiatives and the desire for continuous improvement; (ii) cost, cost reduction, and risk management (avoiding negative environmental impacts and legislation compliance) are the primary drivers; (iii) improving energy efficiency, becoming more attractive to employees (creating a common company culture), reputation and brand image, and profit and sales (pressuring suppliers to meet sustainable standards) were other aspects highlighted as well.

Sánchez-Medina, Corbett and Toledo-López (2011) researched 168 small Mexican handicraft businesses conclude: (i) there is a positive relation between eco-innovation and the three dimensions of sustainability: economic, social, and environmental; (ii) the factors that better explain sustainability are: type of organization, product innovation, and process innovation; (iii) the age of businesses was not a significant factor to explain sustainability; (iv) the handicraft businesses make sustainable decisions more as a result of a desire to maximize profit than because of environmental awareness, which can be explained by the neoclassic vision of economy.

Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010) mapped the current state and future prospects for eco-innovation in Venezuelan SMEs. The mains conclusions obtained analyzing 54 SMEs were: (i) SMEs understand the legal environmental regulations affecting SMEs, but do not perceive the influence of external forces such as the customer demand for green products or fiscal tax incentives; and (ii) eco-efficiency practices are not perceived as an incentive to improve the competitiveness. The environmental strategies are usually adopted aiming to cut down on costs and avoid sanctions and negative effects to the company.

The results of the survey and in-depth interviews applied in Bos-Brouwers (2010) with 26 plastics industry SMEs in Holland brought to light the following barriers to the adoption of eco-innovation: lack of resources (capital, knowledge and competencies), short term management focus and difficulty to radically innovate. Data from two surveys conducted in 257 SMEs from diverse industrial segments in Italy demonstrated the following factors: structural variables of the business (scale economies can support innovative strategies), R&D with focus on sustainability, pressure from the environmental policies and cost of complying with the rules, past performance of the business (capital expenditure, direct/indirect cost, others innovations – techno-organizational non-environmental and quality and nature of the work relations (Mazzanti and Zoboli, 2008). Robinson and Stubberud (2013) analyzed data from Ninety-six thousand Germany SMES identifying the main environmental innovations: reduced energy use per unit of output, reduced energy use to end-user, reduced soil, water, noise or air pollution, recycled water or materials and others.

Vasilenko and Arbačiauskas (2012) compared SMEs with experience in implementation of sustainable innovations and SMEs without such experience identifying a list of eco-innovation drivers. The research in Cagno and Trianni (2013) highlights the importance of public financing for energy efficiency interventions, the importance of external pressures, the need of long-term benefits of eco-innovations, evidence of their willingness to adopt seemingly radical solutions when these are able to improve their long-term competitiveness, the presence in SME of people with ambition and entrepreneurial mind for environmental.

Hansen and Sondergard (2002) conclude that the eco-innovative capability of SMEs is conceived as the result of an interplay between the competencies, the network relations and the strategic orientation of the company, indicating that policy to support SME's adoption of eco-innovations has to take an integrated form, i.e. addressing and developing competence, networks and strategic orientation of SMEs simultaneously whilst remaining systemic and context sensitive. Bocken et al. (2014) investigated the initial phase of the eco-innovation process and the drivers pointed were: the potential revenues, technological advancements, personal reasons, positive experiences and improve the image of SME.

In this same direction, investigating 5222 managers in SMEs of EU Triguero et al. (2013) found that SMEs should see the eco-innovation strategy as a suitable way to increase their potential benefits taken into account the growing environmentally consciousness of European consumers. The relationship between supply and demand factors could also affect market relations, pressures for change, corporate image and reputation, information flows, and cooperation/collaboration/networks influencing the eco-innovation dynamism. The lack of effectiveness of public subsidies/incentives is other cited aspect. Table 3 summarizes the 27 drivers of eco-innovation resulting from the literature review in Web of Science, Ebsco and Scopus.

Table 3 - Synthesis of the literature review of eco-innovation determinants to SMEs

	Triguero et al. (2013)	Bocken et al. (2014) 42	Hansen and Sondergard (2002)	Cagno and Trianni (2013)	Vasilenko and Arbačiauskas (2012)	Brío and Junquera (2003)	Klewitz, Zeyen and Hansen (2012)	Sánchez-Medina, Corbett and Toledo-López (2011)	Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010)	Bos-Brouwers (2010)	Mazzanti and Zoboli (2008)	Robinson and Stubberud (2013)	Klewitz and Hansen (2014)
Available resources (qualify people, time, money)	✓	✓		✓	✓✓	✓	✓	✓		✓			✓
Type of organizational structure: less bureaucracy and more flexibility is better	✓				✓	✓		✓		✓			
Training on environmental issues provided by the management and low employee awareness and environmental training	✓					✓	✓						
Long term strategy is the dominant orientation	✓		✓	✓	✓	✓				✓			
Capability of obtaining radical innovations				✓		✓				✓			
Influence of the production process flexibility on the environmental strategy of SMEs	✓					✓							
The lack of neutrality of regulatory policies may tip the balance in favor of large companies in detriment to the SMEs	✓					✓						✓	
SME-specific actions of technological assistance, awareness and training programs to improve the cooperation with external stakeholders	✓		✓			✓✓	✓		✓	✓	✓		
Desire for continuous improvement				✓			✓✓				✓		
Cost control and risk management to avoid negative environmental impact and compliance	✓						✓			✓	✓	✓	
Improving energetic performance for the company and the market				✓			✓				✓	✓	
Becoming more attractive to employees						✓					✓		

Reputation, brand image and profit margin (pressuring suppliers to meet sustainable standards)	✓	✓				✓						✓
Perception of the strategic relevance of eco-innovation and environmental aspects for the sector and customers		✓			✓	✓	✓	✓		✓	✓	✓
Product and process innovation		✓					✓			✓		✓
Supplier and customer relations as a source of innovative ideas	✓	✓					✓	✓				✓
Existence of a R&D department with focus on sustainability									✓	✓		
Structural variables of the business (economies of scale can support innovative strategies)										✓		
Participation in networks and governmental projects oriented to eco-innovation (e.g. Ecoprofit)	✓		✓			✓					✓	* ✓
Recycling practices and reverse logistics										✓	✓	
Incentives and public financial support (e.g. fee, cost savings associated with implementation of eco-innovations internally)				✓	✓✓							
External pressures of SME sector (e.g. regulation, supplier pressure, rise of energy prices, fees on polluting emissions)		✓	✓	✓								✓
Hiring external consultants and experts				✓								
Obtain long-term benefits to SME				✓								
Motivation and awareness of the founder or management		✓		✓								✓
To adopted eco-innovation methods and tools		✓										
Capability and competence of organizational learning on eco-innovation issues	✓					✓						✓

Caption: ✓ Cited by the author. ✓✓ Quoted by the author as highly relevant or critical determinant.

Analysing the findings in Table 3, and considering as purpose of analysis that the determinant has been cited by four or more authors from literature, it is possible to conclude that the SME should pay attention mainly to (i) the resource constraints (people, time, money); (ii) SME-specific actions, technological assistance, awareness, and training programs that should be taken to enhance the cooperation with external stakeholders (government, universities, other SMEs, research centers); (iii) cost reduction and risk management (avoid negative environmental impacts and compliance); (iv) to regard eco-innovation as relevant and strategic to the sector and to the customers. Moreover, other 22 determinants were cited by two or three authors, indicating that they also are relevant and should not be neglected by the SMEs.

3.3 Research Method

This study is based on qualitative exploratory research and is of interpretative nature. Based on the approach adopted in previous study on eco-innovation in SMEs by Klewitz, Zeyen and Hansen (2012), we chose a qualitative approach to gain greater understanding of the field of study (e.g. the role of determinants to Brazilian SMEs context) as this approach leaves space for insights that were not anticipated by the researcher (Wolcott, 2009).

The research methodology adopted for data collection was planned and performed in several steps. First, a systematic review of literature about eco-innovation in SMEs on Web of Science, Scopus and Ebsco was conducted aiming initially to identify a synthesis of the eco-innovation determinants evidenced in literature. Second, in parallel to this, an open questionnaire was applied with Brazilian eco-innovation experts to identify the drivers to Brazilian SMEs economic context. The answers were synthesized by content analysis of results. Third, a comparative analysis was performed to verify the match of the results of the literature review against the Brazilian SMEs context identifying similarities/differences and intersections/overlaps. Finally, as a result, a list of determinants was obtained for Brazilian SMEs reality. The Figure 1 shows the sequence of research methodology.

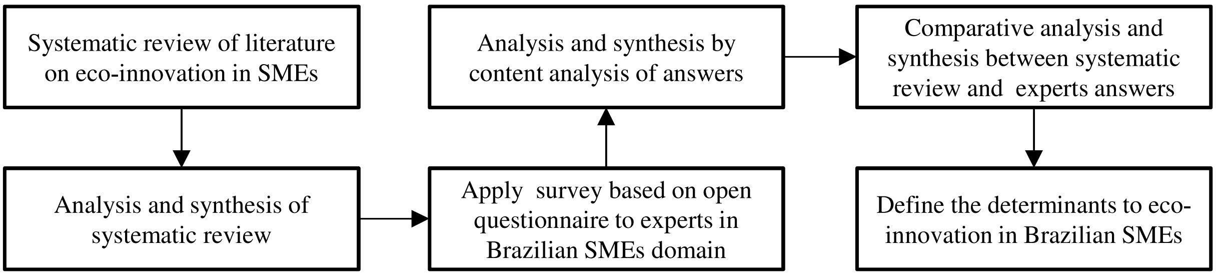

Fig. 1. Research Methodology

The steps of research methodology are detailed as follow. A systematic review of the literature is necessary to understand the state of the art aspects regarding this research topic and to identify pertinent information (Dresch et al., 2015; Tranfield and Denyer, 2003). Was adopted the research protocol suggested by Dresch et al. (2015) and the steps are detailed, beginning with the definition of the issue and conceptual framework is as follows: the purpose of this study is to identify what are the drivers for the implementation of eco-innovation in Brazilian SMEs. The research question of this study is as follows: what are mains determinants for the successful implementation of eco-innovation in Brazilian SMEs? The work team for conducts the search process in scientific databases was formed by authors of this study.

The search strategy included the following inputs: keywords, period, databases, inclusion/exclusion criteria and eligibility/coding. To determine keywords, definitions, and Boolean operators, a preliminary search was performed in Scopus in the field "abstract" and "title." This scientific database was selected because it has been cited in prior studies as a reference regarding the quality and number of publications on eco-innovation.

As a result, we identified a set of keywords in English associated with eco-innovation (‘eco-innovation’, ‘environmental innovation’, ‘sustainable innovation’, ‘green innovation’, ‘innovation ecology’ and ‘clean innovation’). The keywords associated with SMEs also were identified (‘SME’, ‘small and medium-sized enterprise’, ‘small business’ and ‘small enterprise’). All the possible combinations between these keywords were searched for using the following fields: title, abstract and keywords of databases. For example, one of the different combinations of keywords used for this study researched (e.g. ‘SME’ & ‘eco-innovation’). The period considered for this study was between 1995 and 2015. The selected databases included Ebsco Business Source Complete, Scopus and Web of Science. The entire search process reviewed the primary world scientific databases and included more than 35.000 peer-reviewed journals.

The inclusion and exclusion criteria are an important aspect in systematic review studies (Dresch et al., 2015). Such as inclusion criteria, were selected only the studies that fully attended to one or more of these aspects: (i) peer-reviewed papers that were published in English; (ii) studies regarding systematic review in eco-innovation in SMEs; (iii) studies consolidating results of international projects focused in eco-innovation in SMEs with results of large sample. Such as for example the PRIMA Project involving 26 SMEs from Europe (Bos-Brouwers, 2010); (iv) studies on multiples case studies involving several SMEs. Such as for example the study by Sánchez-Medina, Corbett and Toledo-López (2011) involving 168 SMEs. Studies with large samples are best indicated for our research objective, since larger samples represent globally consolidated determinants.

Thus, considering that our objective is to point out determinants for the Brazilian context of SMEs on the whole, this option is the most appropriate. On the other hand, the exclusion criteria included the following: (i) studies with high quantitative or statistical bias; (ii) studies on multiples case studies involving less than three SMEs. (iii) studies with low methodical rigor; (iv) studies proposing methodologies, methods, models or tools in this topic. The results of research process adopted according to Moher et al. (2009) methodology is detailed (Fig. 2).

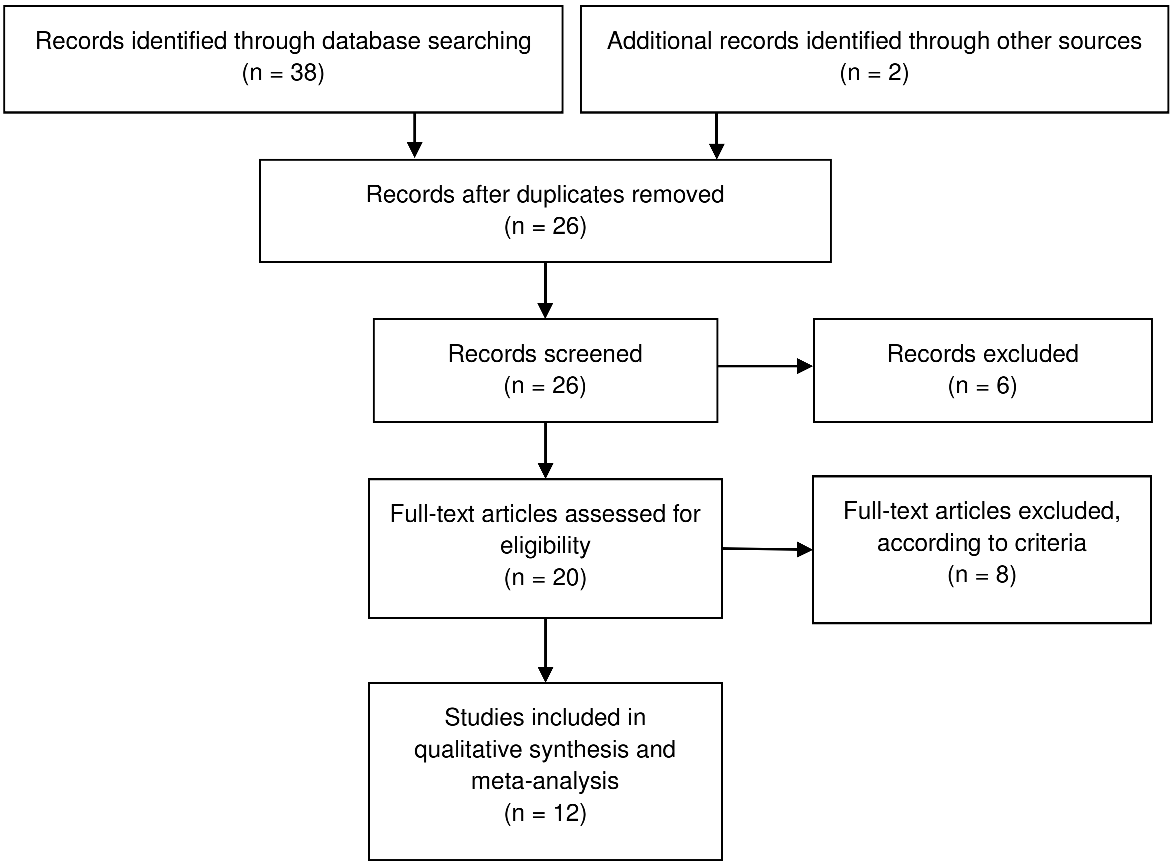

Fig. 2. Synthesis of the research process.

During the process of the search, eligibility and coding, the first search cycle analyzed approximately 40 titles and article abstracts and 26 studies were pre-selected for deeper review. After a detailed content review, 20 articles were selected. Thus, a second search cycle was conducted that analyzed the references of studies that most were frequently cited in the selected papers and adhered to our research goals. In addition, an internet search was conducted to locate any grey literature using a process similar to the database search. The search was finalized, and 12 studies were selected for this study (Table 4).

Table 4 – Selected studies

Author(s)/Year	Title of article	Journal
Brío and Junquera (2003)	A review of the literature on environmental innovation management in SMEs: implications for public policies	Technovation
Klewitz and Hansen (2014)	Sustainability-oriented innovation of SMEs: a systematic review	Journal of Cleaner Production
Klewitz, Zeyen and Hansen (2012)	Intermediaries driving eco-innovation in SMEs: a qualitative investigation	European Journal of Innovation Management

Sánchez-Medina, Corbett and Toledo-López (2011)	Environmental Innovation and Sustainability in Small Handicraft Businesses in Mexico	Sustainability
Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010)	Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives	Journal of Cleaner Production
Bos-Brouwers (2010)	Corporate Sustainability and Innovation in SMEs: Evidence of Themes and Activities in Practice	Business Strategy and the Environment
Mazzanti and Zoboli (2008)	Environmental Innovations, SME Strategies and Policy Induced Effects: Evidence for a District-Based Local System in Northern Italy.	The Icfai Journal of Environmental Economics
Robinson and Stubberud (2013)	Green innovation in Germany: A comparison by business size.	Journal of International Business Research
Vasilenko and Arbačiauskas (2012)	Obstacles and Drivers for Sustainable Innovation Development and Implementation in Small and Medium Sized Enterprises	Environmental Research, Engineering and Management
Cagno and Trianni (2013)	Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises	Applied Energy
Hansen and Sondergard (2002)	Environmental innovations in small and medium sized enterprises	Technology Analysis & Strategic
Bocken et al. (2014)	The front-end of eco-innovation for eco-innovative small and medium sized companies	Journal of Engineering and Technology Management

In the third stage of research methodology (Fig. 2), the data collection consisted of an open questionnaire composed by six questions send to Brazilian experts on eco-innovation. The questionnaire was structured in the follow questions: (i) In your opinion, how can eco-innovation practices contribute to the competitiveness of small and medium-sized enterprises in Brazil? (ii) In your opinion, what competitive advantages could small and medium enterprises in Brazil have in adopting eco-innovation practices in product, service or process innovation? (iii) In your opinion, what are the limiting factors/difficulties/constraints for small and medium-sized enterprises in Brazil to succeed in adopting eco-innovation? (iv) In your opinion, what factors or variables internal to the company should be considered by small and medium-sized enterprises in Brazil to adopt eco-innovation? (v) In your opinion, what factors or variables external to the company should be considered by small and medium-sized companies in Brazil to adopt eco-innovation? (vi) General closing question: In this topic, please feel free to suggest, question and contribute openly to the research, from your point of view on the topic of eco-innovation in small and medium-sized enterprises in Brazil.

According to Ribeiro and Milan (2007), a semi-structured questionnaire consists of a basic interview plan, a set of questions that will be positioned as the interview evolves. The questionnaire was sent to prospective respondents meeting the following criteria: (i) participation in eco-innovation research groups; (ii) author of article on eco-innovation published in a periodical with Journal Citation Report impact factor higher than one (1,0); (iii) to have supervised Ph.D. research work or have published chapters/books on eco-innovation; (iv) being an eco-innovation researcher, participating of some research group in this topic. The Brazilian expert's profile that responds the questionnaire is the follow:

Table 5 - Experts profile

ID	Experts profile
E1	Coordinator of Research Project on eco-innovation in emerging and developed economies. Full professor. Ph.D. and Postdoc in Management.
E2	Researcher on eco-innovation with several papers published. Associate Professor. Ph.D. in Management.
E3	Coordinator of a research project on eco-innovation. Senior research. Ph.D. in Innovation Studies & Development
E4	Coordinator of a research group on eco-innovation, with a large number of articles on eco-innovation published. Assistant Professor.
E5	Researcher on eco-innovation with several researches concluded in eco-innovation. Manager of Brazilian Polo of Technological Innovation. Full Professor. Ph.D. in Production Engineering.
E6	Full Professor and member of a research group on eco-innovation, with books and papers published in eco-innovation.
E7	Senior researcher on eco-innovation with several papers and books published. Full professor. Ph.D. in Management.
E8	Senior researcher on eco-innovation with several papers published. Assistant Professor.
E9	Senior researcher on eco-innovation. Head of Engineering Department. Ph.D. in Engineering.
E10	Coordinator of several research projects on eco-innovation. Head of Department. Ph.D. in Management.

It is important to stress that the construction of the questionnaire followed the guidelines suggested by Hair et al. (2005) for content or face validity, being then validated through a small sample of respondents. Validity is the degree to which a construct measures what it intends to measure. A construct with a perfect validity degree has no measurement errors, and an easy measure of validity would be to check the measurements observed against the true measurement, however, the true measurement is rarely known (Hair et al. 2005).

The questionnaire construction criteria were, in short, the following: the two first questions are intended to relate the connection between the practices and the respective advantages resulting from the eco-innovation. The question three focused on general aspects whereas the next questions are aimed at pinpointing general aspects in external and internal. The specialists' responses were analyzed with content analysis process (Bardin, 2002). Content analysis is another data collection method classified as an observational approach by Hair Jr. et al. (2005) which may be obtained by human observation, mechanical or electronic. Following the content analysis, the specialists' responses were analyzed and consolidated in two ways according to Ribeiro and Milan protocol (2007): (i) internal comparison and by consensus among the respondent; (ii) external comparison: the results were compared with the literature evidence, serving as a reference to identify determining factors and a posterior comparison with the literature findings. In the next sections are detailed these results.

3.4 Results

3.4.1 Descriptive results

The results from literature analysis of selected studies allowed identifying a relation of 27 determinants. This comprehensive relation was consolidated based on several world experiences, and in the main world projects focused sustainable innovations in SMEs (Table 6).

Table 6 – Profile of selected studies

Authors	Project/Data set	Methodology	Region	Sample
Brío and Junquera (2003)	PRIMA Project	Semi-structured interview with director or manager in sustainable innovation activities	Europe Union	26 rubber and plastics SMEs
Klewitz, Zeyen and Hansen (2012)	Ecoprofit Project	Exploratory qualitative interview	Germany	7 metal and mechanical engineering SMEs
Sánchez-Medina, Corbett and Toledo-López (2011)	States with the greatest representation of pottery handicraft businesses	Questionnaires and quantitative analysis	Mexico	168 handicraft SMEs
Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010)	SME Observatory of Venezuela	Questionnaires and quantitative analysis. To compare SME opinions in different countries.	Venezuela	54 manufacturing SMEs
Mazzanti and Zoboli (2008)	Data derived from two surveys of regional projects.	Econometric/quantitative analysis	Italy	257 manufacturing SMEs from Northern Italy

Robinson and Stubberud (2013)	Eurostat's (2011) Community Innovation Survey	Questionnaires and quantitative analysis. To compare SME opinions in different countries.	Germany	96.000 answers
Vasilenko and Arbačiauskas (2012)	SPIN (Sustainable Production through Innovation) and APINI (Institute of Environmental Engineering)	Questionnaires and quantitative analysis	Lithuania	30 manufacturing and services SMEs
Cagno and Trianni (2013)	Database of enterprises which had participated in a regional project	Semi-structured interviews. Multiple case-study.	Italia	71 Italian manufacturing SMEs from Lombardy
Hansen and Sondergard (2002)	ENVIS Project	Multiple case-study.	Five countries from EU	20 SMEs of four sectors
Bocken et al. (2014)	Dutch SMEs who applied for the Prize Het Ei van Columbus for sustainability innovations	Questionnaires and two in-depth semi-structured interviews	Netherlands	42 manufacturing and services SMEs
Triguero et al. (2013)	Flash Eurobarometer Project	Questionnaires and quantitative analysis	Europe Union	5222 SMEs' managers

By analysis of Table 6 is possible conclude that: (i) the most of the studies on eco-innovation in SMEs context available in literature were developed in EU; (ii) regarding to the methodology adopted, semi-structured interviews and questionnaires followed by quantitative analysis are the most common research method; (iii) SMEs of manufacturing segment are the most frequent sample investigated by literature.

We also applied the software Publish or Perish (Harzing, 2007) to identify the total number of citations that appeared in the studies that were selected for analyses (Table 7). Publish or Perish is a software program that retrieves and analyzes academic citations using Microsoft Academic Search and Google Scholar to obtain, analyze and present metrics regarding raw citations. The following criteria were used to analyze the citations: (i) Total number of citations denotes the sum of all citations in all studies; (ii) An average number of citations per year indicates the number of citations in the studies divided by the number of years included in the result set. These results were obtained on 11 December, 2016.

Table 7 – Landscape of citations

Author	Total number of citations	Average citations per year
Brío and Junquera (2003)	301	23,15
Klewitz and Hansen (2014)	141	70,5
Klewitz, Zeyen and Hansen (2012)	45	11,25
Sánchez-Medina, Corbett and Toledo-López (2011)	8	1,6
Fernández-Viñé, Gómez-Navarro and Capuz-Rizo (2010)	41	6,83
Bos-Brouwers (2010)	253	42,17
Mazzanti and Zoboli (2008)	9	1,13
Robinson and Stubberud (2013)	14	4,67
Vasilenko and Arbačiauskas (2012)	15	3,75
Cagno and Trianni (2013)	60	20
Hansen and Sondergard (2002)	69	3,83
Bocken et al. (2014)	47	23,5

The study with the largest number of citations (301) was conducted by Brío and Junquera (2003). A possible explain to this is may be the date year of publication mixed with the diffusion of the theme of eco-innovation from the 2000s. The purpose of the study was to collect the most important contributions to the economic literature about the special characteristics of the management of the environmental innovation in the SMEs, showing their strengths and weaknesses about the way public administrations face this situation.

Moreover, the study with the largest index of average citations per year (70,5) was the one by Klewitz and Hansen (2014) that despite being recent, had an exceptional average of citations per year. This study literature review analyzed the heterogeneous picture research in the past 20 years with a focus on the innovation practices including different types of eco-innovation and strategic sustainability behaviors of SMEs. The study by Bos-Brouwers (2010) article also is highlighted. This research use insights from innovation theory, sustainable development practice and SMEs characteristics to unlock new knowledge on factors that influence the translation of eco-innovations within SMEs into practice. These studies may be considered a possible emergent study in this research field.

3.4.2 Contributions and advantages of eco-innovation to Brazilian SMEs

This section presents the results of content analysis of results of the questionnaire applied with Brazilian experts. The first question is an opening and general question about how can eco-innovation practices contribute towards the competitiveness of small and medium-sized enterprises. The expert E1 stated that eco-innovation contribute increasing internal efficiency in the use/consumption of resources in SMEs. Besides, contributes to cost reduction, reliability in production processes, less exposure to price volatility and supply of basic inputs (energy and water), the lower capital commitment of the company with provisions for labor, environmental and civil liabilities. Eco-innovation also improves competitiveness in the development of market niches and enable the positioning in rigorous markets. E4 corroborate argued that *"SMEs who wish to go into the international market (USA and Europe) have a higher probability of achieving competitive advantages with eco-innovation*".

The increase in profit margin and differentiation in products/services of small business was noted by several authors (E1, E3, E5, E6, E8). The impact on the image of the company in the market also was highlighted. E10 and E8 say that an eco-innovation can lead a company to improve its image to the stakeholders. E2 complement affirming that some of the eco-innovation practices require investments to generate gains or reduction of cost while some will not produce financial benefits but rather other types of return (image enhancement).

The increase of competitive results also was noted. To E4 contribute enabling competitive results distinct and to E6, a strategic market positioning. Investing in eco-innovation practices will allow SMEs to achieve distinct competitive results (E4). He also recognizes that few enterprises sectors recognize and valorize socio-environmental issues in their businesses. However, a possible disadvantage is that SMEs' customers in low economies or in on development countries could leave purchase products, services or processes due the price increases for the costs involved to implement the eco-innovation.

E5 argued that product eco-innovations change the way of produce. He also complements stressing the survival of the world economic system will increasingly depend on organizational skills and the creation and improvement of sustainable economic processes. Eco-innovations also contribute to cost reduction. This is obtained with reduction consumption of natural resources (E7). To E8 minimize not only costs but also generates opportunities to engage in projects, programs, receiving seals, awards, and access to other strategic partners (environmental entities, consulting companies, associations, class entities, suppliers, competitors, etc.).

Eco-innovations practices may contribute to the consolidation of environmental management of enterprises, allowed obtain both economic and ecological gains at the same time (E9). Finally, E10 note the importance of eco-innovation practices to SMEs competitiveness highlighting that every environmental problem is an efficiency problem.

The second question treats specific on products, services and processes eco-innovation, analyzing what competitive advantages the SMEs could expect achieve by adopting eco-innovation for products, services, and processes. In this direction, to E2 the adoption of a significant number of eco-innovations in products, services, and processes contributes to the reduction of costs generally in the medium and long term, with the reuse/recovery of waste and to avoid sanctions by oversight. SMEs gain competitive advantage by reducing costs and also by anticipating a trending market that will be irreversible in a few next years, perhaps decades: that natural resources are limited and therefore require a great deal over the price of production (E3).

E4 note that the expected competitive advantages to SMEs are the differentiation in the medium and long term and the consolidation of a socio-environmentally compromised image. Nonetheless, this involves investments in technology, research, and development, as well as strategic pro-action partnerships in the consumer market.

One of the main advantages of eco-innovative products, services and processes would be the acquisition of new clients, given the fact of growing importance of the environmental issue in our society. The opening of the company to new markets, a differentiated positioning for suppliers and increased profitability through the gains from the efficient use of its resources can also be considered possible competitive advantages (E6). On the whole, the value added to the enterprise is expected (E5).

The adopting eco-innovation for products, services and processes also will increase the market share and improvement in the image of the company before stakeholders (E7). In addition, to leads the SME to have a better image in the market, E9 cite economic gains coupled with environmental gains, the reduction of consumption of toxic raw materials, reduction waste, and the reduction of generation and disposal of materials.

E8 state that in products and services can be obtained through serving a niche that even small will valorise and pay for products that have a sustainable bias, such as a life cycle of clean development mechanisms or recyclable packaging. While on processes perspective, primarily the competitive advantages are based on resource saving and in the green marketing that can be generated from innovative and sustainable processes.

3.4.3 Barriers to eco-innovation in Brazilian SMEs

This section presents the results regarding the point of view of experts on the third question that inquired what are the limiting factors, difficulties or constraints for Brazilian SMEs to succeed in adopting eco-innovation. As a result, was possible to obtain a list of factors that blocked the diffusion of eco-innovative practices. Based on responses, was possible concluded that the mindset of SMEs' managers is an important barrier to the the dissemination of eco-innovation in SMEs. To E1 there is a managerial myopia about the importance of innovation and sustainable innovation as an element of its business strategy. He also adds that the SMEs tend to consider the expenses with eco-innovations as a cost rather than investment. Finally, the Brazilian consumer market, in many segments, still does not recognize the importance and, nor is it willing to pay more for a sustainable product. Besides the necessary investment costs, the lack of capacity/knowledge and cultural issues should also be considered (E2). E3 notes the lack of resources and complement saying which may be more difficult to perceive (or amortize) the value of investment in SMEs that invest in eco-innovations.

Among the limiting aspects E4 highlights that: (i) in general, the owners of small and medium-sized Brazilian companies adopt a reactive stance to the market, they stand in wait instead of a proactive stance; (ii) there is no culture of investment in innovative technologies and R&D in SMEs through agreements with universities and research centers, for example; (iii) there is a predominance of the thought that returns should be obtained in the short term; (iv) low awareness of the need to invest in socio-environmental aspects. And when this occurs, it is motivated by the mandatory legislation in view of the specific sector in which the company operates;

(v) due to the fact that Brazil is a rich country in terms of natural resources, this makes the population in general and the entrepreneurs themselves are not yet sufficiently concerned with nature.

For E5 the main factors that can represent difficulties are: (i) lack of personal qualified to planning and implement eco-innovation practices; (ii) the manager's understanding of the concept and applicability of eco-innovation; (iii) the manager's view on the economic and social benefits prior to the adoption of eco-innovative practices; (iv) immediacy of the manager to obtain economic results; (v) the resistance to investment in a new type of professional within the company to implement the tool, and (vi) the resistance to innovation, that is, to change the way in which products have always been designed and produced.

As well as E4 and E5, the expert E6 highlights the lack of knowledge about how to incorporate eco-innovations is a constraint. He also extends underlining that unfolds strategic environmental objectives into actionable actions is a challenge to SMEs. The aspects related to costs also are relevant to small enterprises: "*It is common for SMEs to work with low-profit margins, which leads to the prioritization of other issues*."

Already E7 argue the barriers are very similar to those of innovation practices. The need for effective implementation of the innovation regu lamentation and laws, the need for an eco-system of innovation (seed money, incubators, and technology parks), the shift of emphasis from schools (mainly in engineering schools) to the integration of projects between universities and companies are the mains limitations. E8 corroborate this opinion adding: (i) the lack of public policies; (ii) the lack of cooperation between SMEs with universities and other research institutes; (iii) the absence of information sharing among the agents of the same activity, branch, business, production chain; (iv) high cost for SME to technology development and R&D; (v) the lack of culture of entrepreneurs and managers, who according to Innovation Research (PINTEC) carried out by the Brazilian Institute of Geography and Statistics (IBGE), in their vast majority, see as innovation the acquisition of machines, software and equipment.

Besides financial limitations, E9 suggests the internal culture of employees for change and an innovative position of SME, the lack of professionals with knowledge in eco-innovation, and especially about sustainability and environmental management. Likewise, E10 finalize, stating that a higher level of ecological awareness and scarce innovative tradition may be an obstacle. The resistance to hiring qualified professionals to implement eco-innovation in SMEs apparently was no previously linked in the literature with the common reality of lack of economic conditions of SMEs. This kind of resistance, as well as the strength in change way which products have always been designed and manufactured, can be related with the lack of the managers' understanding and awareness about eco-innovation concept and benefits. A similar finding was obtained in Robinson and Stubberud (2013, p. 48) that stated: "Many SMEs are reluctant to engage in eco-efficiency, possibly because they equate 'green' with 'expensive'.

3.4.4 Internal variables impacting eco-innovation in Brazilian SMEs

The fourth topic of questionnaire looked to identify what factors or internal variables should be considered by Brazilian SMEs in order to adopt eco-innovations. The primary objective of this question was obtaining a consensus on the strategies that should be prioritized by companies to minimize the effects of previous barriers identified. According to E1, the internal variables that should be considered by SME towards eco-innovation are three. The first is regarding human capital. It is necessary people with the perception that sustainability. As a consequence, this must be a fundamental element in the strategic, tactical and operational plan of the organizations. Second is R&D. There is a need to develop an internal and fundamentally external R&D structure (relationship with institutes and universities) for the development of innovation projects in this area. Currently, multiple development agencies support research resources in companies, so it is possible to think about R&D in small and medium-sized companies. Third, are the internal processes in all areas that valorize and promote sustainability practices in companies.

The most relevant internal factors are the capacity and awareness that the adoption of eco-innovations is an investment that will generate benefits that are often not measurable economically (E2). In this same direction, to E3 it is necessary that the management of SME be open to the changes that involve the actions under the paradigm of environmental responsibility. After that, the values related to this paradigm must be communicated to all of the company.

Corroborating E1, according to E4 internally must have a permanent policy of allocating budgetary resources for the development of new eco-innovative products, services and processes, either by an own R&D department or by partnering with other companies or by an agreement with universities/institutes. However, this depends on the perception and awareness of the entrepreneur that he will have a return on the investment made there. As well as, overcome the resistance of sharing their knowledge, experiences and control over their resources externally with other companies and stakeholders. Similar variables were related by E5 that note as factors to be considered the existence of qualified personnel, the capacity to invest in project and re-design, time destined for the encouragement and orientation of the team of employees to implement the philosophy of eco-innovation, reorganization of production processes. He also added an interesting aspect related to the analysis of the marketing team's ability to plan campaigns to promote new products based on eco-innovation in the market.

Structural internal variable typically found in SMEs were related as a priority to specialist E6. He said that the financial situation of the company is an important factor to be considered, because the monetary gains from eco-innovations may not be achieved in the short term. And this aspect is not interesting for SMEs context that have a short budget. Furthermore, the size of the company also has a relevant weight, since small enterprises have few financial, technological and human resources, turning difficult to allocate resources to the company's innovation projects. The existence of a motivated member concerning the environmental issue (Environmental Champion) must also be considered. Finally, the position of SME in the value chain should be evaluated. Those that are closer to the end of the chain tend to suffer greater external pressures to adopt sustainable practices in their process, leveraging eco-innovation practices in the firm.

Corroborating previous findings, E7 also underlines that creating an internal culture of innovation is an important factor. According to E9 the change of managerial culture and the culture collaborators for innovation, sustainability, is a foundation of very well consolidated environmental management. As well as, professionals with experience in entrepreneurship, innovation and on sustainable actions (processes and products). Finally, to E10 the internal variables that should be considered by SMEs in eco-innovation transition are the teamwork, work cooperation and every human resource management policy, the existence of a transformational leadership (agreeing with to E6), strategic integration, good communication between departments and a strong R&D department.

3.4.5 External variables impacting eco-innovation in Brazilian SMEs

Several external variables affect the successful adoption of eco-innovative practices. Particularly the national and international legislations have changed and become increasingly rigorous with business practices and their impacts on society and the ecosystem around the company (E1, E3, E6, E8, E10). This changes the competitive conditions between companies, in so far as there is the possibility of competitors adopts the same paradigm (E3, E6). Therefore, the SME should ask itself ‘how are my competitors (re) acting on sustainable issues?’ Furthermore, the environmental pressures of stakeholders should be evaluated, such as changes in the behavior of the supply chain in which the SME is positioned (E6).

Regarding costumer perspective, results highlighted that there is an on-going change in the behavior and form of consumer interact with companies and their products, where sustainable issues have become qualifying criteria (E1, E5, E8, E9). It is necessary for SME to find on the market the desire to absorb sustainable products. Only in this way will the entrepreneur invest in this type of innovation (E9). According to another expert (E5) external factors or constraints are: (i) consumer acceptance of sustainable products; (ii) the existence of materials in sufficient quantity to supply production based on eco-innovation, and (iii) the valorisation of professionals qualified to act with eco-innovation initiatives within companies.

Another well related external variable is the available resources to Brazilian SMEs realize eco-innovations projects. There are international and national investment funds through development banks that provide resources to eco-innovative projects (E1). However, the access to funding sources needs to be facilitated and less bureaucratized (E2). Furthermore, the SMEs should work collaboratively on networks to access knowledge and other resources needed to minimize the lack of access to financial resources (E7).

That is, SMEs need to open their processes to the external environment to obtain knowledge and information. This is a necessary cultural and mind-set change. In this direction, a factor external to the relevant companies in the process of adoption of eco-innovations is the reduction of the distance between the business and the academic sectors. Universities and companies do not have the same rhythm and do not always adopt the same language. In addition, their goals are distinct and the approach is laborious and requires tolerance and abdication of status and power of both parties (E4).

3.4.6 Enhancing the diffusion of eco-innovation in Brazilian SMEs

Lastly, the closing question of the questionnaire provided an opportunity for comments and general contributions of experts. In this direction, E1 affirms that the Innovation Research (PINTEC) carried out by the Brazilian Institute of Geography and Statistics (IBGE) should include small and medium-sized spending on eco-innovation in their periodical reports. Moreover, understanding the motivations, results and diffusion of eco-innovations in small companies is something that can contribute to the literature, as well as how to discuss and address cases of failure.

E3 highlights that it is important to reflect on the impact of eco-innovation on business return. Is it necessary to assess whether this impact is tangible, is measurable? Or will it be intangible for a period and bring profits only in the long term? It is important to understand how entrepreneurs faced this challenge. He concludes stating: *"In my opinion, having long-term thinking should bring more positive impacts to eco-innovation in the company than otherwise."*

There are opportunities for further studies on overcoming the distance between research centers and academy and SMEs to develop eco-innovations. On the one hand, researchers are distant from the practical application of their experiments to the market. On the other hand, entrepreneurs are expecting a quick return on their investments and adopting a waiting stance with consumers instead proactively facing the market (E4).

The eco-innovation is based on an evolutionary perspective of innovation in which innovation emerges through a systemic process that refers to the interrelationship and dynamic interaction between different actors and internal and external factors that influence the innovation process. These assumptions motivate the exploration of the wide range of eco-innovation as well as, the analysis of changes in various dimensions of eco-innovation that consist of design, user, product and process aspects. The definitions of eco-innovation are very general, and for this reason, many types of innovation can be considered eco-innovations. This situation results in an important question of how eco-innovation can be classified to understand its characteristics better and turn them into differentials for the industry to become sustainable (E5).

E8 suggests that one of the factors that could promote the diffusion of eco-innovation is in the sharing and the technological cooperation. In Brazil, many initiatives work well in some segments and take a long time to expand to others. This was the case with biodigestors, which had been used in swine for 30 years and only recently were used in the chain of products derived of manioc. Another aspect is the lack of a specific entity to turn public the results (cases of success and best practices) that are often are published in academic papers, but do not reach the public domain. In the same way that Enterprise of Technical Assistance and Extension Rural (EMATER) and Brazilian Agricultural Research Corporation (EMBRAPA) are responsible for the promotion of agricultural technical knowledge, Brazilian Service of Support to Micro and Small Enterprises (SEBRAE) in support of SMEs E8 believes that a dedicate organism is necessary in order to foster eco-innovation. To conclude, E10 affirm that eco-innovation is supported on local circumstances and on global management and both aspects must be integrated.

3.5 Discussion of Results

Initially, the specialists' responses were consolidated in order to identify convergence and divergence about eco-innovation practices and their respective advantages, and concerning general factors, internal and external to Brazilian SMEs as well. Table 8 consolidates the specialists' view about the topics related to the practices and advantages of eco-innovation.

Table 8 - Contributions of eco-innovation to SMEs

Major eco-innovation contributions to SMEs context	Author
Increasing internal efficiency in the use and consumption of resources	E1, E5
Cost reduction and reliability in the production processes	E1, E2, E3, E7, E8, E9
Less exposure to price volatility and supply of basic inputs (e.g. energy and water)	E1
Lower capital commitment of the company with provisions for labor, environmental and civil liabilities	E1
Eco-innovation of products, services, business, and management processes increases competitiveness and the development of new markets, mainly in international markets.	E1, E4, E5, E6, E10
Increase profit margin and in differentiation in products/services in the medium and long term	E1, E3, E4, E5, E6, E8
Improves the brand and image of SME.	E2, E8, E10

An analysis of Table 8 primarily demonstrates that the specialists agree about the potential advantages associated with increased competitiveness, cost reduction, brand enhancement and improved company image and about the possibility of deploying different strategies of cost and differentiation. Nevertheless, a possible disadvantage noted is that SMEs' customers in low economies or in on development countries could leave purchase products, services or processes due the price increases for the costs involved to implement the eco-innovation. This appointment is conflicting with the following aspect resulting from another expert point of view: some of the eco-innovation practices require investments to generate gains or reduction of cost while some will not produce financial gains but rather other types of return (image enhancement).

Regarding advantages with the adoption eco-innovation answered in the second question, the results show that the increase in profit margin and market share and improved image to stakeholders are the most common advantages. These related advantages are obtained from the conquest of new customers due to the growing importance of the environmental issue in our society, in products/services may be obtained by attending to serve a niche market that even small, valorise and paid more for products that have a sustainable bias. Besides, new markets, differentiated positioning for suppliers and increased profitability, can be obtained through gains from the efficient use of resources (E6). Generally, the differentiation and consolidation of a socio-environmentally compromised image are achieved in a medium and long term perspective. And this trajectory includes investments in technology, research, and development, as well as strategic partnerships with the market (E4).

The increase in value aggregation and the cost reduction in SMEs might be obtained as result of the reduction of the use of natural resources and the green marketing generated from innovative and sustainable processes. The cost reduction generally occurs in medium and long term and also minimizes the possibilities of penalties part of inspectorate entities. Finally, the adoption of eco-innovation in SMEs takes the anticipation of a global trend that will be irreversible in a few years or decades, considering that natural resources are limited and contribute significantly to the cost of production and sale, and the current level of consuming tends to increase with scarce resources.

3.5.1 Barriers to adoption of eco-innovation

To complement these findings, Table 9 presents the summary of barriers and limitations pointed by specialists that may block the diffusion of eco-innovation in Brazilian SMEs.

Table 9 – Barriers to adoption of eco-innovation

Barriers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
The awareness and understanding of SMEs about eco-innovation proposal	✓				✓				✓	
Consider eco-innovation spending as a cost and not as an investment	✓									✓
The necessary costs to implement eco-innovative practices and the financial standing of the SMEs		✓				✓				
The need for skilled professionals to plan for and implement eco-innovation		✓			✓				✓	
Owners of SMEs with reactive attitude to the market and not one proactive				✓						
The need to invest in innovative technologies, research and development (R&D) in conjunction with universities, research centers, and external agents				✓				✓		
The SMEs management's immediatist culture to achieve quick results and a short term vision of management				✓	✓					
Low awareness of SME on benefits of eco-innovation and the need to invest in socio-environmental aspects and when this occurs is motivated by the mandatory legislation				✓	✓					
Cultural resistance to innovating and doing things differently					✓					✓
The inclusion of eco-innovation into the strategy of SME						✓				
Costumers acceptance, cultural aspects and awareness of customers on sustainable products	✓	✓								
The existence of an ecosystem of eco-innovation (seed money, incubators, technology parks)							✓	✓		
The need of change of emphasis in schools (mainly Engineering schools) for the integration of projects between university-companies							✓			
Lack of public policies encouraging the SME cooperation with universities and research centers								✓		
Lack of information sharing among agents of the same activity, branch, business or productive chain								✓		

The analyses of these consolidate results turn possible to identify fifteen principal related barriers to Brazilian scenario. The lack of innovation culture of Brazilian entrepreneurs and managers may be illustrated according to PINTEC (IBGE) reports. These data reveal that the entrepreneurs, in their vast majority, comprehend the innovation as the acquisition of machines, software and equipment (E8). Based on the analysis results is possible to consider that the level of awareness on sustainability between SMEs' managers and society as a whole in income economies such as the Brazilian still is in the early stage, if compared with well-developing countries.

As a consequence, some barriers to adoption of eco-innovation may be considered more critical to Brazilian context. In this direction, the concordance between the results literature review and specialists, demonstrated that the awareness and understanding of SMEs about eco-innovation proposal leading the SMEs to consider eco-innovation spending as a cost and not as an investment, the immediatist culture to achieve quick results and a short term vision of management, the low awareness of SME on benefits of eco-innovation, the costumers acceptance and sustainable awareness may be considered the main barriers.

This set of factors can be highlighted as the more influencing constraints for the diffusion of eco-innovation practices in an income economy such as Brazil. To conclude, is possible affirm that the main contribution of these limitations is in consolidate the main factors that should be considered to SMEs not only in an internal perspective, but also by policy makers, in an external perspective, in order to increase the adoption of eco-innovation in small companies.

3.5.2 Principal Determinants to Eco-innovation

Furthermore, the findings resultant of the fourth and fifth question presented the internal and external variables related to SME that should be considered by Brazilian enterprises aiming successfully when implementing eco-innovation practices. This set of variables might consider the most relevant determinants to minimize the existence of barriers discussed previously to the Brazilian context.

Table 10 – Internal and external determinants

Internal and external determinants	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
The need for skilled professionals to plan for and implement eco-innovation practices	✓				✓				✓	✓
The need to invest in innovative technologies, research and development (R&D) in cooperation with universities, research centers and external agents.	✓			✓						
Internal culture and processes promoting and encouraging eco-innovation practices	✓		✓	✓	✓		✓		✓	
The understanding of the SMEs about eco-innovation concepts		✓								
Awareness on economic, social and environmental benefits from eco-innovation		✓	✓						✓	
Internal policy of allocating budgetary resources for the development of new eco-innovations	✓			✓	✓					
Structural internal variables of SME such as short budget, size and						✓				

technological resources										
The existence of an “eco-innovator leader” or “Environmental Champion” leading the diffusion of eco-innovative practices						✓				✓
The SME’s position in the supply chain: enterprises closer to the end of the chain are more liable to suffer external pressure to adopt sustainable practices in their processes, leveraging eco-innovation						✓				
Participating in cooperating SME networks							✓			✓
Changes in national and international legislations and regulation of the sector where the SME operates	✓		✓			✓		✓		✓
Awareness of consumers to buy green products and incentives to buy eco-innovative product/services	✓				✓	✓		✓	✓	
The existence of raw materials in sufficient quantity to supply production based on eco-innovation					✓					
The access to international and national investment funds in eco-innovation	✓	✓								
Resistance to innovate doing things differently and owner’ mind-set			✓	✓						
Capacity of the marketing sector to divulge new eco-innovative products				✓						

The analysis of internal and external determinants shows that the financial condition of the small company is an important factor to be considered since the gains from eco-innovation may not be short-term, which is not interesting for companies with low budgets. Besides, small companies generally have scarce financial, technological and human resources, which make it harder to allocate resources for the company's innovation practices. For this reason, the cooperation with universities, research centers and external agents, or the participation in cooperating SME networks can be underlined as crucial determinants and pathways to these Brazilian companies.

Furthermore, other internal determinants are related with directly with the conditions and internal culture of Brazilian SMEs. The first is the lack of internal culture and processes promoting and encouraging eco-innovation practices. The second is the internal policy of allocating budgetary resources for the development of new eco-innovations. Third, is related with hiring skilled professionals to plan for and implement eco-innovation projects.

On the other hand, several external determinants on which small companies have no control affect the potential of diffusion of eco-innovative practices significantly. For that reason, the changes in national and international legislations and regulation of the sector where the SME operates and the awareness of consumers to buy green products and incentives to buy eco-innovative product/services must be mitigated with governmental programs. In the same line, the access to international and national investment funds in eco-innovation should be facilitated with governmental proactive programs/actions.

Another interesting comparative analysis performed in this research is the comparison between the findings from specialists' opinion against the determinants found in the literature review on SMEs as a whole, and mainly SMES hosted in EU, as previously discussed (Table 3 and 6). The outcome of this analysis demonstrates that there for some determinants some degree of similarity between the Brazilian context and the previous literature. In the internal perspective, the determinants related both to Brazilian context and literature are: the organizational structure (less bureaucracy and more flexibility is better), available resources and structural variables of small business (qualify people, time, money), the motivation/awareness of the SME' owner/management, long term strategy as dominant orientation, the perception and awareness of the strategic relevance of eco-innovation and environmental aspects of the sector and customers, the presence of a R&D department with focus on sustainability, and the capability/competence of organizational learning of SME on eco-innovation issues.

On another hand, on the external perspective, the determinants found both to Brazilian context and in the literature are: the lack of neutrality of regulatory policies may affect the balance in favour of large companies in detriment to the SMEs, the existence of specific actions of technological assistance, awareness and training programs in order to improve the cooperation of SME with external stakeholders, the reputation, brand image and profit margin (pressuring suppliers to meet sustainable standards) and the impact of external pressures of SME segment (e.g. regulation, supplier pressure, rise of energy prices, fees on polluting emissions).

The comparative results between Brazilian experts and the results of literature review also permitted identify a list of determinants found in the literature review but that do not a direct correspondence relation with the ones cited by the specialists. Between them is highlighted the following determinants: the capability of obtaining radical innovations, cost control and risk management to avoid negative environmental impact and compliance, becoming more attractive to employees, analyse the cost control and risk management to avoid negative environmental impact and compliance, improve the energetic performance for the company and the market, adopt recycling practices and reverse logistics and to adopted eco-innovation methods and tools. These results, particularly may suggest that some of these determinants (become attractive to employees, cost control and risk management avoiding negative environmental impact and compliance, and energetic performance) are directly related with the larger maturity and consolidate regulations of EU on sustainable practices in comparison with the context of income economies such the Brazil.

In contrast, the results also present a set of determinants found to Brazilian SMEs context, but without a direct correspondence with the determinants of literature. In this sense, is possible say that the diffusion of an internal culture/processes promoting/encouraging eco-innovation practices and allocating budgetary resources, the existence of an “eco-innovator leader”, the absence of an ecosystem facilitating eco-innovation activities in SMEs, and the access to international/national investment funds to develop eco-innovations reflect, in a wide perspective, the immature stage of eco-innovation concept in Brazil.

In specific about the importance of green products to leverage the diffusion of eco-innovation in SMEs, a recent research topic discussing the integration between Lean and Green practices has gaining attention in the literature. Measuring the influence of different methods derived from both the Lean and Green approaches, Fercoq, Lamouri and Carbone (2016), concluding which the integration of them results enable a solid waste minimization program in manufacturing.

In this same direction, Johansson and Sundin (2014), conclude that a stronger focus on value creation for customers, as advocated in Lean Product Development (LPD), is positively associated with Green Product Development (GPD) implementation. Furthermore, none of the concepts present limitations regarding industrial applicability. Therefore, LPD and GPD might be linked as methodologies enablers of eco-efficiency and of sustainability, resulting in eco-innovations due to the capability in reduce several kinds of waste, and continually search for perfection and wastes elimination. This culture has potential to leverage mainly environmental innovation in process and eco-friendly products.

In short, the overall findings obtained with the literature review and the internal comparison of Brazilian SMEs context with the literature, have brought to light a relevant list of determinants that SMEs should take into consideration when eco-innovation is implemented. Moreover, our findings propose distinct determinants suggested to Brazilian SMEs. Hence, our research extends the current list of determinants available in the literature. In a nutshell, is possible affirm that the primary objective proposed at the beginning of this research has been achieved. In turn, probably the main scientific contribution of this research is to indicate that there are a set of critical determinants that have frequently been cited by specialists and also because are present in the literature review. These research contributions can drive governmental programs, investments and internal management practices to increase the diffusion of eco-innovation in Brazilian SMEs.

3.6 Conclusions and further research directions

The discussion of eco-innovation, although recent, has been achieving increased relevance in the international context. The present study has proved that the theme is still incipient as a general theme, mainly in connection with the particular impact of eco-innovation in small and medium-sized enterprises (SMEs). Based on the review of the literature on eco-innovation, an initial list of critical factors was organized. The content analyses of specialists' point of view allowed finding similarities, overlaps and exclusion aspects between the determinants.

Outcomes show that several difficulties hinder a diffusion of sustainable innovation in Brazilian SMEs context. Moreover, a clear disadvantage to small business is that the most of the existent literature focus mainly on large enterprises overlooking the significant contribution of SMEs to the global economy. To fill this research gap, the practical implication of this research is generating new knowledge on factors that influence the translation of eco-innovations within SMEs into practice to emergent economies, such as the Brazil. Our study contributes to scientific research discussing a set of alternatives aiming a more fluid internalization of eco-innovation to Brazilian SMEs context.

Another important contribution of our research is the identification of opportunities and themes for future research on this emergent field. The first is the development of pragmatic methods of SMEs to create an internal process and product eco-innovations. Second, is the proposition of frameworks and model to drive SMEs implementation. It is suggested that such a model, should contemplate the diverse constituting elements of eco-innovation such as institutions, public and private organizations, market, education and infrastructure. Third, the validation of suitable systemic indicators of innovation-oriented to SMEs and based on empirical research. Fourth, are strategies to disseminating the practice of technology transfer offices (bridging institutions) across the country. These agencies may work as promoters of eco-innovation and interaction between universities and enterprises. Benefits of this initiative include the dissemination of eco-innovative practices and improved technological competitiveness of the country, through the patent deposit. Another research opportunity is the proposition of models and strategies for disseminating the scientific culture of meeting the demands of enterprises and the society through the education and training of young researchers. Finally, researches focused on the identification of the major obstacle to the dissemination and implementation of eco-innovative projects has emerged as an opportunity for research since such barriers are associated with technical questions and to the perception of the environmental issues by the scientific and business community.

Some limitations of research also need to be mentioned. The first limitation is regarding with the process of review of the literature, primarily based on the Ebsco, WoS and Scopus databases. Further researches could include different scientific databases not contemplated. A second aspect is that we decide to include only peer-reviewed papers that were published in the English language. Studies in others languages could be inserted in new researches to expand the analysis. Third, we included studies consolidating results of international projects focused in eco-innovation in SMEs showing results of an extensive set of sample and multiples case studies. Studies covering individual case studies also may be added to further research in this theme.

The findings show that the present study as well as in the results of literature review, none research focusing the factors that prevent the SMEs from achieving the same levels of competitive advantage in sustainable innovations of large organizations. Explore this research gap might be a significant opportunity for further studies in this field. Furthermore, our findings showed that the classification of eco-innovation topic need be better understood. Hence, a good starting point to this goal would be identifying the existing typology in theoretical research and the respective impact of the typology according to the following key points: do they produce for end consumers or for other companies? Are these SMEs new entrants in a particular market or well-established organizations? Finally, research on how to integrate local circumstances and the global management is suggested. To conclude, is possible affirm that the practical contribution of this study is on the consolidation of a comprehensive framework of eco-innovation to Brazilian SMEs. This study provides important insights and challenges to academics, policy makers, and practitioners to improve the diffusion of eco-innovative practices.

Acknowledgments

This research was supported by the Portuguese Foundation for Science and Technology (FCT) and the Brazilian Council for Scientific and Technological Development (CAPES/CNPq) under grant number 230916.

REFERECENCES

Andersen MM (2008) Eco-innovation: towards a taxonomy and a theory. In: DRUID Conference 25, Copenhagen, DK, 1-16.

Arundel A, Kemp R (2009) Measuring eco-innovation, UNI-MERIT Research Memorandum, 2009-2017.

Barbieri J C et al. (2010) Innovation and sustainability: new models and propositions. RAE 50 (2):146-154.

Bardin L (2002) Content analysis. Lisboa: Edições 70.

Blackburn WR (2008) The sustainability handbook.Washington: Environmental Law Institute.

Blackburn WR. (2007) The Sustainability Handbook: The Complete Management Guide to Achieving Social, Economic and Environmental Responsibility. Washington, DC: ELI Press.

Bocken, N.M.P., Farracho, M., Bosworth, R., Kemp, R. 2014. The front-end of eco-innovation for eco-innovative small and medium sized companies. J. Eng. Technol. Manage. 31: 43–57.

Borghesi S, Crespi F, D'Amato A, Mazzanti M., Silvestri F (2015) Carbon abatement, sector heterogeneity and policy responses: Evidence on induced eco innovations in the EU. Environmental Science & Policy 54: 377-388.

Bos-Brouwers HEJ (2010) Corporate Sustainability and Innovation in SMEs: Evidence of Themes and Activities in Practice. Business Strategy and the Environment 19: 417–435.

Brio JA, Junqueira B (2003) A review of the literature on environmental innovation management in SMEs: implications for public policies. Technovation 23: 939–948.

Brunswicker S, Vanhaverbeke, W (2015) Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. Journal of Small Business Management 53 (4): 1241–1263.

Cagno, E., Trianni, A. 2013. Exploring drivers for energy efficiency within small-and medium-sized enterprises: First evidences from Italian manufacturing enterprises. Applied Energy 104: 276–285.

Carrilo-Hermosilla J, Gonzales PDR, Konnola T (2009) Eco-innovation: when sustainability and competitiveness shake hands. New York: Palgrave Macmillan.

Chapin FS, Kofinas GP, Folke C (2009) Principles of ecosystem stewardship: resilience-based natural resource management in a changing world. Springer, New York, USA.

del Río P, Peñasco C, Romero-Jordán D (2015) What drives eco-innovators? A critical review of the empirical literature based on econometric methods. Journal of Cleaner Production, In Press.

Diedrich A, Upham P, Levidow L, van den Hove S (2011) Framing environmental sustainability challenges for research and innovation in European policy agendas. Environmental Science & Policy 14 (8): 935-939.

Doorn N (2011) Exploring Responsibility Rationales in Research and Development (R&D). Science, Technology & Human Values 37 (3): 180-209.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research:A Method for Science and Technology Advancement. Springer. pp.161.

Fernández-Viñé MB, Gómez-Navarro T, Capuz-Rizo, SF (2010) Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives. Journal of Cleaner Production 18 (8): 736-746.

Foxon T, Andersen MM (2009) The greening of innovation systems for eco-innovation -towards an evolutionary climate mitigation policy. In: DRUID Summer Conference - Innovation, Strategy and Knowledge, Copenhagen, DK.

Freeman C, (1996) The greening of technology and models of innovation. Technological forecasting and social change 53 (1): 27-39.

Fussler C, James P (1996) Driving Eco-Innovation: a breakthrough discipline for innovation and sustainability. London, Pitman Publishing.

Govindan, M.E., PhD., K., Tseng, M-L., Tan, K. H. & Geng, Y. 2016. Sustainable consumption and production in emerging markets. International Journal of Production Economics. 181, p. 261-265

Gronum S, Verreynne ML, Kastelle T (2012) The Role of Networks in Small and Medium-Sized Enterprise Innovation and Firm Performance. Journal of Small Business Management 50 (2): 257–282.

Hair Jr, JF, Babin B, Money AH, Samouel P. Research Methods in Management. Porto Alegre. Editora Bookman. 2005.

Hansen, O.E., Sondergard, B., Meredith, S. 2002. Environmental innovations in small and medium sized enterprises. Technology Analysis & Strategic Management 14 (1): 37-56.

James P (1997) The Sustainability Circle: a new tool for product development and design. Journal of Sustainable Product Design 2: 52-57.

Kemp R, Foxon TJ. Tyology of Eco-Innovation. In: MEI project: measuring Eco-Inovation.In: www.merit.unu.edu/MEI/deliverables/MEI%20D2%20Typology%20of%20eco-innovation.pdf.

Kemp R, Pearson P (2008) Measuring eco-innovation, final report of MEI project for DG Research of the European Commission.

Klewitz J, Hansen EG (2014) Sustainability-oriented innovation of SMEs: a systematic review. Journal of Cleaner Production 65 (15): 57-75.

Klewitz J, Zeyen A, Hansen EG (2012) Intermediaries driving eco-innovation in SMEs: a qualitative investigation. European Journal of Innovation Management 15 (4): 442-467.

Love JH, Roper S (2015) SME innovation, exporting and growth: A review of existing evidence. International Small Business Journal 33 (1): 28–48.

Maes J, Sels L (2014) SMEs' Radical Product Innovation: The Role of Internally and Externally Oriented Knowledge Capabilities. Journal of Small Business Management 52 (1): 141–163.

Maçaneiro MB, Cunha SK (2010) Eco-Innovation: A Framework for Future Research. In: XXVI Innovation Management Symposium, ANPAD, Vitória, BR.

Maçaneiro MB, Cunha SK (2012) Eco-Innovation: a reference framework for future research. Revista Innovare 13 (1): 266-289.

Maryse M.H, Chappin WJV, Vermeulen M, Meeus TH, Hekkert MP (2009) Enhancing our understanding of the role of environmental policy in environmental innovation: adoption explained by the accumulation of policy instruments and agent-based factors. Environmental Science & Policy 12 (7): 934-947.

Massis AD, Frattini F, Pizzurno E, Cassia L (2015) Product Innovation in Family versus Nonfamily Firms: An Exploratory Analysis. Journal of Small Business Management 53 (1): 1–36.

Mendonça, ATBB, Cherobin APMS, Cunha SK (2012) Sectorial Systems Sustainable Innovations: analysis of categories, types and measurement measures. In: XXVII Innovation Management Symposium, ANPAD, Salvador, BR.

Mazzanti M, Zobloi R (2008) Environmental Innovations, SME Strategies and Policy Induced Effects: Evidence for a District-Based Local System in Northern Italy. The Icfai Journal of Environmental Economics 6 (1): 7-34.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. 2009. The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097.

OECD. Policy Brief: Sustainable Manufacturing and Eco-innovation: Towards a Green Economy. June 2009a. Avaible in: <http://www.oecd.org/dataoecd/34/27/42944011.pdf>.

OECD. Sustainable manufacturing and eco-innovation: Framework, Practices and Measurement. Synthesis Report Paris: OCDE, 2009b. In: http://www.oecd.org/dataoecd/15/58/43423689.pdf

Ozaki R, Shaw I, Dodgson M (2013) The Coproduction of Sustainability Negotiated Practices and the Prius. Science Technology Human Values 38 (4): 518-541.

Rashid N, Jabar J, Yahya S, Samer S (2015) State of the Art of Sustainable Development: An Empirical Evidence from Firm's Resource and Capabilities of Malaysian Automotive Industry. Procedia - Social and Behavioral Sciences 195: 463-472.

Raymond L, St-Pierre J (2013) Strategic capability configurations for the internationalization of SMEs: A study in equifinality. International Small Business Journal 31(1): 82–102.

Reid A, Miedzinski M (2008) Eco-innovation: Final report for Sectoral Innovation Watch, Technopolis Group, Brighton.

Rennings K (2000) Redefining Innovation - Eco-Innovation Research and the Contribution from Ecological Economics. Ecological Economics 32: 319 – 332.

Ribeiro JLD, Milan, GE (2007) Entrevistas individuais: teoria e aplicações. Fundação Empresa Escola de Engenharia da UFRGS.

Robinson S, Stubberud HA (2013) Green innovation in Germany: A comparison by business size. Journal of International Business Research 12 (1): 47-56.

Sabadie JA (2014) Technological innovation, human capital and social change for sustainability. Lessons learnt from the Industrial Technologies Theme of the EU's Research Framework Programme. Science of the Total Environment 481: 668-673.

Sánchez-Medina PS, Corbett J, Toledo-Lopez A (2011) Environmental Innovation and Sustainability in Small Handicraft Businesses in Mexico Sustainability 3: 984-1002.

Tranfield, D., Denyer, D. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Triguero, A., Moreno-Mond, L., Davia, M.A. 2013. Drivers of different types of eco-innovation in European SMEs. Ecological Economics 92, 25-33.

Vasilenko, L., Arbačiauskas, L. 2012. Obstacles and Drivers for Sustainable Innovation Developmentand Implementation in Small and Medium Sized Enterprises. Environmental Research, Engineering and Management, 2(60): 58-66.

Wilts H, Dehoust G, Jepsen D, Knappe F (2013). Eco-innovations for waste prevention-Best practices, drivers and barriers. Science of The Total Environment 461–462: 823-829.

Wolcott, H. (2009), Writing Up Qualitative Research, 3rd ed., Sage Publication, Thousands Oaks, CA.

Wynarczyk P, Piperopoulos P, McAdam M (2013) Open innovation in small and medium-sized enterprises: An overview. International Small Business Journal 31(3): 240–255.

CAPÍTULO III

The main implications and contributions of this Chapter to this thesis were the following:

- The findings of this chapter made a theoretical contribution to PSS field clarifying the debate concerns the sustainable impact of PSS.
- This chapter exposed the foundations on which the limitations of PSS reinforce the controversy on its real sustainable impact to both companies and society.
- A very recent increase interest by 'sustainable product-service system' topic in past recent years was noted.
- Was confirmed the hypotheses that PSS and SPSS might be considerate distinct, although no totally independent disciplines.
- On one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. On the other hand, SPSS concept is based on eco-efficiency and in a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy.
- Hence, based in the previous benefits and in the impact on the society, SPSS discipline was included in the scope of this thesis.
- Was identified a research gap regarding how the tension between more sustainable and eco-innovators products and eco-services can be best managed was identified.
- Was identified a need of the proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and End-Of-Life) in order to minimize the effects of lack of competence of SMEs supporting the sustainable transformation.
- A special look to the SMEs should be given. They are a key actor to the global economy. At least 80% of all global enterprises are considered SMEs (Moore and Manring, 2009) and according to European Commission (2011) SMEs represent with over 99% of European enterprises and two-thirds of European employments.

4 Artigo 3: Product-Service Systems and Sustainable Product-Service Systems: Two sides of same coin? Systematic review and research implications

Abstract

Currently there is in research community a heated controversy debate concerns the sustainable impact of PSS and the understanding that sustainability is not an intrinsic advantage of PSS business model. As consequence, abroad this discussion, recently a promising perspective, the Sustainable Product-Service Systems (SPSS) has received attention from academy. Due the novelty of this discussion, a limited stock of knowledge is available to academics and practitioners. Thus, in order to clarify this discussion, the main objective of this research is obtain the understanding abroad this debate investigating if really PSS and SPSS are independents concepts and identify possible aspects that may explain these research streams. A systematic literature review (1995-2016) was performed following a structured research protocol. Results from descriptive analyses contributed with knowledge regarding the evolution and focus of publications on PSS and SPSS, the channels where the research communities share their studies and the most representative scholars, regions and research groups in both topics. A very recent increase interest by SPSS in past two years was revealed. Findings based on systematic review confirm the hypotheses that PSS and SPSS might be considerate distinct, although no totally independent disciplines. On one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. On the other hand, SPSS concept is based on eco-efficiency and on a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy. This findings are based on several perspectives analysed, such as the content analyses of evolution definitions on PSS and SPSS since their origins, on the need to redefine the current patterns of consumption/production in order to not compromise the boundaries of resources available, sum up with the several distinct research communities and research streams identified and the low effective practical diffusion of sustainability in traditional PSS offers evidenced by literature. In short, this study extends the current theory framework on PSS discipline guiding the communities interested in this domain to unlock the present and future challenges on service-

oriented economy. Further key research directions are proposed to advance towards a more sustainable and Circular Economy based on SPSSs.

Keywords: Product-Service Systems. Sustainable Product-Service Systems. Circular Economy. Systematic review.

4.1 Introduction

The literature emphasizes the imperative need for shifting from unsustainable production and societal patterns to sustainable ones (Almeida et al., 2017). Since the first researches, the PSS business models has been labelled as an environmentally-friendly business model mixing together the two main themes of sustainability and business models. However, actually the literature discuss if PSS is capable of delivering the expected benefits, mainly for environmental aspects (Annarelli et al., 2016). Currently, there's in research community a heated controversy debate concerns the sustainable impact of PSS such as innovative systems. The PSS concept was initially considered to be a promising initiative to influence on sustainable production and consumption patterns. However, it is now stated that PSS do not necessarily lead to sustainable solutions (Boucher et al., 2016). A look in their origins might help to understand these expectative.

The origin of PSS as a research field is intimately associated with the origins of Service Economy and mainly from propositions by Giarini and Stahel (1993). They are considered the pillars of PSS field development (Tukker, 2015). "In the Service Economy, the real issue - in terms of economic value - appears to be the maximization of the combined utilization of products and services during their life time, an operation which takes into account a series of costs prior to, during, and after production. On the one hand, the traditional notion of economic value is linked to the existence and marketability of a product. On the other hand, the notion of economic value in the new Service Economy is extended to include the period of utilization" (Giarini and Stahel, 1993, p. 42-43).

One of firsts formalized definitions formalized on PSS stated that a product service-system is a system of products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models (Goedkoop et al., 1999). Is possible conclude, therefore, that the initial idea of lower environmental impact (Goedkoop et al., 1999) and extended the life cycle of products

(Giarini and Stahel, 1993) of solution offered to market, make part of intentions of PSSs approach.

Nevertheless, actually there is in the literature the understanding that the sustainability is not intrinsic characteristic of PSS (Doualle et al., 2016; Pigosso and McAloone, 2016; Boucher et al., 2016; Kjaer et al., 2016). Previous studies have demonstrated that PSS business models may indeed have a negative effect on the environmental issues, resulting only in economic benefits (Barquet et al., 2016a; Halme et al., 2004; Tukker, 2015; Doualle et al., 2016).

Tukker (2015, p. 88) corroborate affirming that PSS is not the sustainability panacea. Renting, leasing and sharing can have environmental benefits since, in principle, the same service level can be achieved with the use of fewer artifacts. In this same direction Boucher et al. (2016, p. 1) recently stated that “The PSS concept was initially considered to be a promising initiative to influence on sustainable production and consumption patterns. But it is now stated that PSS do not necessarily lead to sustainable solutions”.

As consequence, this lack of trust in PSS's environmental friendliness resulted in a separation of two research streams between academics. In one hand, the studies focused on sustainability dealing with analyses of environmental/social impact, and in other hand, research communities on strategy and business models almost completely ignoring these aspects (Annarelli et al., 2016). In this context, abroad this discussion, recently a promising perspective named as Sustainable Product-Service Systems (SPSS) has received attention from academics.

SPSS can be defined as “an offer model providing an integrated mix of products and services that are together able to fulfil 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” (Vezzoli et al., 2015, p. 2). Barquet et al. (2016a, p. 436) defined SPSS as “an approach to achieve benefits in the three dimensions of sustainability”. Therefore, this research streams now proposed, differently from traditional PSS statements and definitions, advocate that the SPSSs are intrinsically embedded in a Triple Bottom Line (economic, social and environmental) perspective of sustainability.

Hence, considering these two research streams presents in literature, the main objective of this research is obtain a deeper understanding abroad this discussion investigating if really these two concepts are independents, and if they really are, identify possible the elements and challenges related with the transition process that explain this aspect. In this sense, based on the proposition that there is an emergent discussion on the real potential of PSS on sustainability being addressed by different research communities, this research seeks to obtain a more detailed understanding of knowledge production both within and across them. To clarify this research gap, a literature review was performed in Scopus and Web of Science databases looking for studies discussing this question. Complementary materials based in seminal studies also were in included to enrich the discussion made. Furthermore, a detailed analysis through the origins and evolution until the present of PSS and SPSS concepts was concluded.

The relevance of our research is identify and presented to research communities new insights to this discussion on these two research streams. This study also extends the current theory framework on PSS and SPSS. In this manner, our results provide an integrative and organising lens for viewing the various contributions to knowledge production on the PSS and SPSS. Similar to research proposed on the field of servitization in Lightfoot et al. (2013), the main outcomes of this literature review are the understanding about where these two research streams are discussed across research communities, where interactions and communications are stronger and where the common areas of investigation are located. The remainder of this paper is organised as follows. The Section 2 presents the reviews of literature and main definitions. Section 3 presents the research method and protocol of systematic review carried. Section 4 discussed the descriptive results. Section 5 discusses the research results and their management and scientific implications and contributions to PSS and SPSS topic. Finally, Section 6 presents the final discussions, conclusions and keys research directions.

4.2 Theorical Background

4.2.1 Product-Service Systems (PSS)

To better comprehend the current PSS research field, it is necessary verify their origins. It is possible stated that one of pillars of PSS field was the following statement:

> "Waste prevention and recycling is therefore one of the key economic concerns of the Service Economy. **In the Service Economy, the real issue - in terms of economic value - appears to be the maximization of the combined utilization of products and services during their life time, an operation which takes into account a series of costs prior to, during, and after production**. On the one hand, the traditional notion of economic value is linked to the existence and marketability of a product. On the other hand, the notion of economic value in the new Service Economy is extended to include the period of utilization" (Giarini and Stahel, 1993, p. 42-43). (Highlighted by author)

It is possible perceive that, in spite be presented in 1993, the ideas by Giarini and Stahel are still very contemporary. The authors are considered the pillars of PSS field development by Tukker (2015).

In this same line, Ness (2009) affirm that Walter Stahel recognized, in the early 1980s, that extending the "use-life" of goods was an essential part of a transition to a more sustainable society (Stahel, 1982). Stahel also linked product life extension to the "utilization-focused service economy," differentiating between sale, rental, and "selling system utilization" (Stahel, 1994). According to Tukker (2015, p. 75-76) "[…] authors such as Walther Stahel (1982) and Friedrich Schmidt-Bleek et al. (1993) were pioneers in identifying the benefits of the PSS concept in terms of sustainability and resource-efficiency". This interest in PSS for environmental reasons has received a new boost from the recent revival of interest in resource-efficiency among important actors in civil society, business and government.

In the same line, Wise and Baumgartner (1999, p. 133), in the paper "The new profit imperative in manufacturing" published on Harvard Business Review contributed with the new comprehension of customer relationship in the perspective of Service Economy:

> "In the new world of manufacturing, the sturdiest barrier to competition is customer allegiance. The goal is not necessarily to gain the largest share of customers but to gain the strongest relationships with the most profitable customers. By earning their loyalty, a manufacturer can become their preferred supplier of services throughout the product life span".
> **"Delivering a great product is not enough to gain a customer's allegiance. You have to deliver a combination of services that minimizes the overall costs associated with owning and using the product.** Xerox has come to understand this. The company is succeeding in selling large copier systems by emphasizing how the copier and associated Xerox services will reduce expenses for labor, archiving, and retrieval, thereby lowering customers' document-management costs. In the process, Xerox is building stronger, more proprietary relationships with its customers." (Highlighted by author)

By analysis of proposition by Giarini and Stahel (1993) and Wise and Baumgartner (1999) is possible comprehend the origins of still current central ideas of PSS definition. Even though, several authors have continually proposed different conceptualizations to PSS since 1990s until the present, there are proximity of theses PSS' definition with the Wise and Baumgartner (1999) and Giarini and Stahel (1993) seminal ideas.

Therefore, the concept of PSS has been discussed since the 1980s and is possible state that early studies greatly influenced the development of this new field were the researches by Stahel (1982, 1993), Wise and Baumgartner (1999), Goedkoop et al. (1999), Mont (2001), Morelli (2003), Tukker (2004) among others.

The following concepts proposed by Ceschin (2014) help to comprehend the PSS:

Products: the tangible artefacts of the system.

Services: they include services that make products available (sales services, renting, sharing, etc.), and services to manage products in the use and end-of-life phases (maintenance, upgrading, take back, etc.).

Network of actors: it includes all the socio-economic actors needed to produce and deliver the PSS, and it comprises the partnerships and interactions between those actors belonging to that particular value chain or "value constellation".

Infrastructures: they comprise existing collective and private systems (such as roads, communication lines, waste collection systems, etc.). PSS and infrastructures are strictly correlated: infrastructures affect the configuration of the PSS and at the same time the PSS can stimulate the development of new infrastructures or the modification of existing ones.

Structure: the physical structures (infrastructure, technologies, resources, materials), institutional structures (rules, regulations, power structures) and economic structures (market, financing, consumption, production). Changes in structure comprise changes in how actors organise the things they do, either physically, institutionally or economically.

Culture: the sum of shared images, norms and values that together constitute the perspective from which actors think and act. Changes in culture comprise shifts in thinking, mental models and perceptions.

Practices: the sum of activities (routines, behaviour). Changes in practices comprise changes in what actors actually do, how they work or behave.

Landscape: the landscape is the relatively stable social, economic and political context in which actors interact and regimes and niches evolve.

By analyses of literature, is suggest have the concordance between the academics on the classification proposed by Tukker (2004) about the eight PSS categories. The most of papers adopt this categorization (Figure 1).

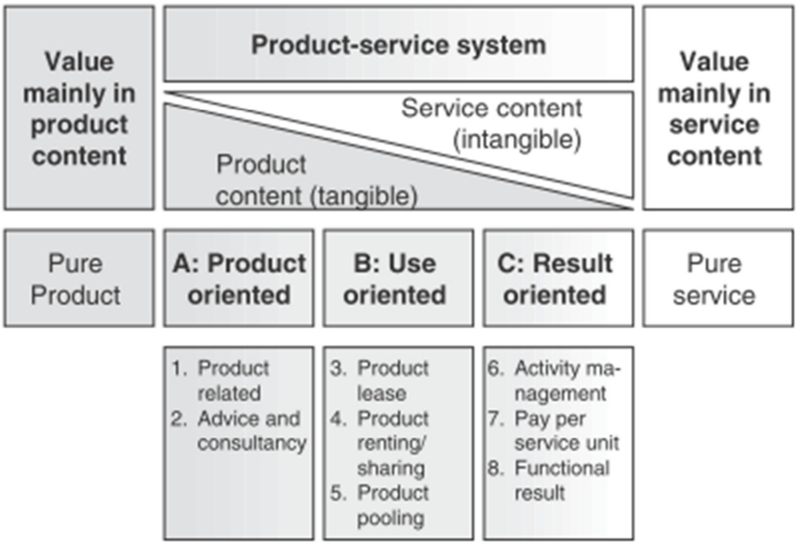

Fig. 1. Main categories and subcategories of PSS. Source: Tukker (2004).

For this reason, this research adopts the PSS definition proposed by Tukker (2015): A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.

In the first category, the main offering still consists of products, but some extra services are added. In the second one, the ownership of product remains of the provider/seller and is made available to users, who pay for its use and not for possession. In the third category, the actors (provider and client) agree upon a result, without any or with few predetermined conditions. A shared consensus has been reached on PSS categories: product-oriented, use-oriented and result-oriented services (Assanelli et al., 2016). The definition to each category and subcategory is detailed according the original statement by Tukker (2004):

Product-oriented services. Here, the business model is still mainly geared towards sales of products, but some extra services are added. The two subcategories are:

Product-related service. In this case, the provider not only sells a product, but also offers services that are needed during the use phase of the product. This can imply, for example, a maintenance contract, a financing scheme or the supply of consumables, but also a take-back agreement when the product reaches its end of life.

Advice and consultancy. Here, in relation to the product sold, the provider gives advice on its most efficient use. This can include, for example, advice on the organizational structure of the team using the product, or optimizing the logistics in a factory where the product is used as a production unit.

Use-oriented services. Here, the traditional product still plays a central role, but the business model is not geared towards selling products. The product stays in ownership with the provider, and is made available in a different form, and sometimes shared by a number of users. The three subcategories are:

*Product lease***.** Here, the product does not shift in ownership. The provider has ownership, and is also often responsible for maintenance, repair and control. The lessee pays a regular fee for the use of the product; in this case normally he/she has unlimited and individual access to the leased product.

*Product renting or sharing***.** Here also, the product in general is owned by a provider, who is also responsible for maintenance, repair and control. The user pays for the use of the product. The main difference to product leasing is, however, that the user does not have unlimited and individual access; others can use the product at other times. The same product is sequentially used by different users.

*Product pooling***.** This greatly resembles product renting or sharing. However, here there is a simultaneous use of the product.

Result-oriented services. Here, the client and provider in principle agree on a result, and there is no pre-determined product involved. The three subcategories are:

*Activity management/outsourcing***.** Here a part of an activity of a company is outsourced to a third party. Since most of the outsourcing contracts include performance indicators to control the quality of the outsourced service, they are grouped in this paper under result-oriented services. However, in many cases the way in which the activity is performed does not shift dramatically. This is reflected by the typical examples for this type, which include, for example, the outsourcing of catering and office cleaning that is now a commonplace in most companies.

*Pay per service unit***.** This category contains a number of other classical PSS examples. The PSS still has a fairly common product as a basis, but the user no longer buys the product, only the output of the product according to the level of use. Well known examples in this category include the payper-print formulas now adopted by most copier producers. Following this formula, the copier producer takes over all activities that are needed to keep a copying function in an office available (i.e. paper and toner supply, maintenance, repair and replacement of the copier when appropriate).

*Functional result***.** Here, the provider agrees with the client the delivery of a result. This category is used in this article, in contrast to activity management/outsourcing, for a functional result in rather abstract terms, which is not directly related to a specific technological system. The provider is, in principle, completely free as to how to deliver the result. Typical examples of this form of PSS are companies who offer to deliver a specified 'pleasant climate' in offices rather than gas or cooling equipment, or companies who promise farmers a maximum harvest loss rather than selling pesticides.

The seminal study by Baines et al (2007) also discussed ideas necessary to a deep comprehension of PSS. Baines et al. (2007) stated that, traditionally, many people have considered products separately from services. However, recent years have seen the 'servitization' of products and the 'productization' of services. Baines et al. (2007) cited the paper by Morelli (2003) which sees 'servitization' as the evolution of product identity based on material content to a position where the material component is inseparable from the service system. Similarly, 'productization' is the evolution of the services component to include a product or a new service component marketed as a product (Fig. 2).

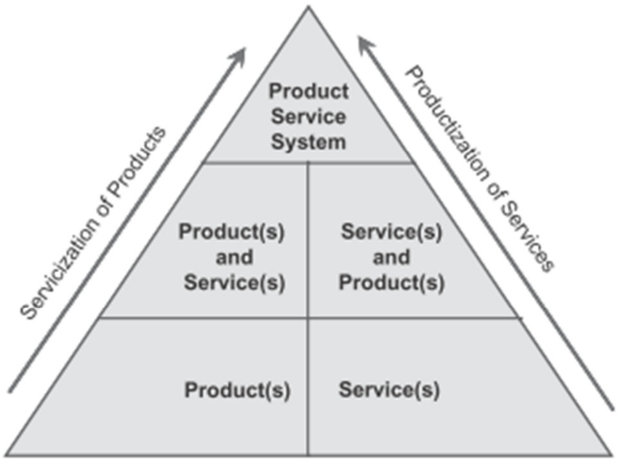

Fig. 2. Evolution of the Product Service-System concept. Source: Baines et al. (2007).

The convergence of these trends is the consideration of a product and a service as a single and integrates offering or a PSS offer.

4.2.2 Engineering integrated PSS perspective

The design and development of a PSS raises new issues since the service component introduces further requirements than traditional product engineering. Compared to physical products, services are generally under designed and inefficiently developed. For this reason, approaches such as New Service Development, Service Design and Service Engineering have emerged during the years to support the design and development of service either as a system itself or as a constituting element of a PSS. However, only Service Engineering investigates service design and development with a systematic perspective and with a seamless integration of product and service contents Based in the most of definition aligned considering the PSS such a system, other elements help the understanding of its whole structure and ecosystem (Cavalieri and Pezzotta, 2012).

From this definition in the PSS context, the fundamental elements to be considered for a complete understanding of PSS Engineering domain (Cavalieri and Pezzotta, 2012) are:

4.2.2.1 Service Engineering

Service Engineering is an emerging technical discipline whose foremost aim is to provide a "systematic development and design of services using suitable models, methods and tools as well as the management of the service development process (Aurich et al., 2010). Sakao and Shimomura (2007, p. 592) define as: “a discipline to increase the value of artifacts and to decrease the load on the environment by reason of focusing service".

Systems Engineering is conceived as an interdisciplinary approach and means to enable the realisation of a system and its constituent **entities**, interacting with the most relevant **stakeholders** and **actors** throughout the system's **life cycle** (Cavalieri and Pezzotta, 2012).

Entities can be real or abstract, tangible or intangible whose relationship forms the PSS as a whole. System content (tangible, intangible) and channel are the main entities defining a PSS. The channel is used to transfer, amplify and control the contents. Considering the PSS definition by Mont (2002): "PSS is a system of products, services, networks of actors and supporting infrastructure that continuously seeks to be competitive, satisfy customer needs and have a lower impact than traditional business models"; the channel can be further split into networks of companies that may jointly fulfil customer needs, and existing collective and private infrastructures.

Actors. The Service Engineering view require designing business architectures in which networks of customers, suppliers and alliance partners maintain consistent levels of quality, while allowing for minor variances in ends and means. To reach this purpose, the involvement of the value chain **actors** is one of the main pillars of the PSS development. It is also important to define and understand the role of different actors inside and outside the process development along the whole life cycle of a system (Cavalieri and Pezzotta, 2012).

PSS are forcing a new understanding of relationships and many stakeholders are involved in the provision of sustainable and ecological solutions. However, to consider customers and stakeholders as key resources, the development process has to be redefined, and new activities must be encouraged throughout the life cycle phases. The aim in service development is to create prerequisites for long-term profitable customer relations and to attract and keep customers who are satisfied and loyal along the different life cycle phases (Cavalieri and Pezzotta, 2012).

The **main actors** involved in a PSS (Lindahl et al., 2006; Cavalieri and Pezzotta, 2012) are the following:

Customer or End-User: to engineer the Product–Service, customers' needs and diversity have to be known for the identification of the requirements throughout the PSS life cycle phases. The customer can be involved either in an active, as co-designer or co-producer, or in a passive way, as a mere source of information.

Channel: all the actors involved along the channel need to be considered within the engineering process due to their intermediary role between the manufacturer and the customer.

Society and environment: refers to the actors operating in the PSS business ecosystem. In our understanding, they can be related to laws and regulations, which allow a proper functioning of the ecosystem.

Life cycle. Cavalieri and Pezzotta (2012) stated that an exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases. Manufacturing firms, in order to increase revenues, have to provide services during the complete life cycle of the physical product. Thus, a successful offering and realisation of a PSS extends the involvement and responsibility of the provider throughout the entire life cycle: from the design and realisation (Beginning of Life, BOL), to the usage and maintenance (Middle of Life, MOL) and the dismission (End of Life, EOL). The authors defined these terms as following:

The Beginning Of Life (BOL) including design and manufacturing: identifying requirements, defining specifications, doing a more and more detailed design, developing prototypes and performing tests and finally the manufacturing.

In the Middle Of Life (MOL) the product is in the hands of the customer, who uses it, and is supported by the manufacturer or providers for maintenance. It also includes external logistic, distribution.

In the **End Of Life (EOL)** the product is retired or upgraded by the manufacturer and disposed by the customer. Products are retired in order to be recycled. EOL is the phase where products are collected, disassembled, refurbished, recycled, reassembled, reused or disposed. To consolidate these concepts a system view of PSS Engineering is expressed (Fig.3.).

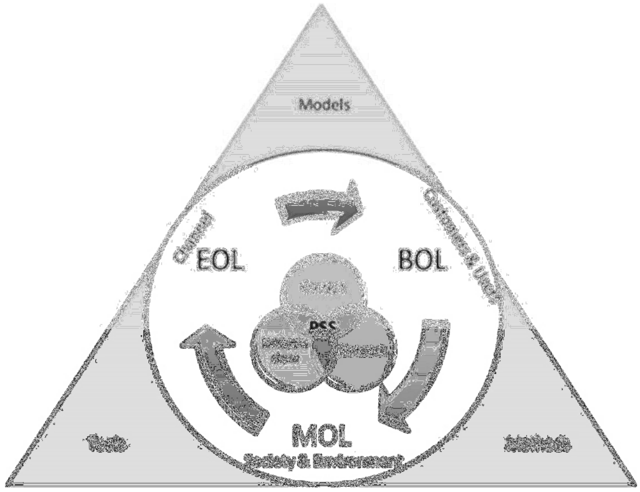

Fig. 3. A system view of PSS Engineering. Source: Cavalieri and Pezzotta (2012).

According to Kowalkowski et al. (2017b) in the most cited publication on service in manufacturing companies is Oliva and Kallenberg (2003). Oliva and Kallenberg proposed one of the first process theories for service growth and its service transition concept has had major influence in the research domain, regardless of academic discipline. It found that in most of the firms sampled, the transition is a deliberate transformation effort that involves disruptive developments of new capabilities as response to strategic threats and opportunities. For each of these disruptions (i.e., steps) they identified the series of triggers, goals, and actions normally deployed, and argued that the adoption of new services seemed to be based on a trial and error capability-centred development.

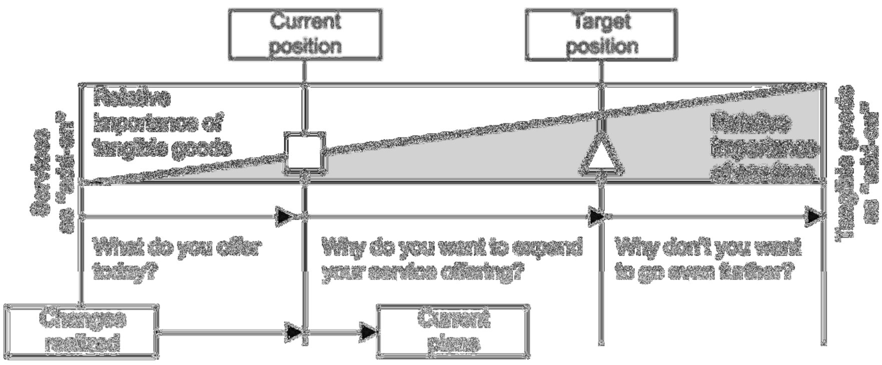

Fig. 4. The product-service continuum research design. Source: Oliva and Kallenberg (2003, p. 162).

It is, however, interesting to note that the transition framework that they used to design the inquiry (Fig.4.) has been interpreted as a proposal of a smooth and continuous evolution towards more services, although they clearly state that that such evolution is not expected and, indeed, did not find evidence for it. Oliva and Kallenberg (2003) were also the first to articulate the potential cultural conflict between the existing product and the emerging service organizations (Kowalkowski et al., 2017b).

PSS represent hybrid products that consist of an immaterial component, the service part, as well as a material good, the product. While traditionally products and services are developed independently and organized in different departments, the concept of PSS targets to an integrated product and service offering. Hence, depending on the PSS configuration variable amounts of service and product can be present and the ratio can continuously change over time (Fig. 5), for example due to technological developments or of changing customer needs.

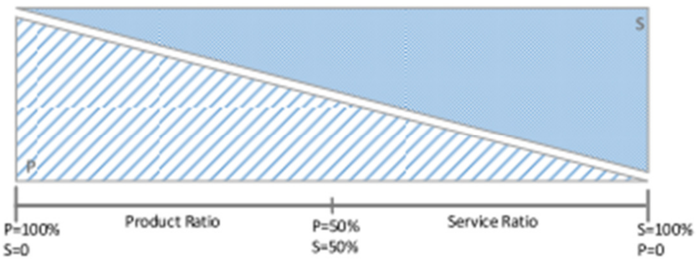

Fig. 5. Variable configuration of PSS. Source: Niemöller et al. (2014).

To make a quantitative differentiation of the ratio of PSS components, a distribution on a percentage basis of each PSS part can be made. The less service ratio (S) in a PSS is present, the higher is the product proportion (P). As long as both components are used as a combination the integration can be called a Product-Service System. Only if one of the PSS components is discontinued and e.g. merely the proportion of product is 100%, the composition is no longer a PSS and thus no hybrid power bundle (Niemöller et al. (2014). This same analyse can be made in the perspective of value proposition orientation of firm (Fig. 6).

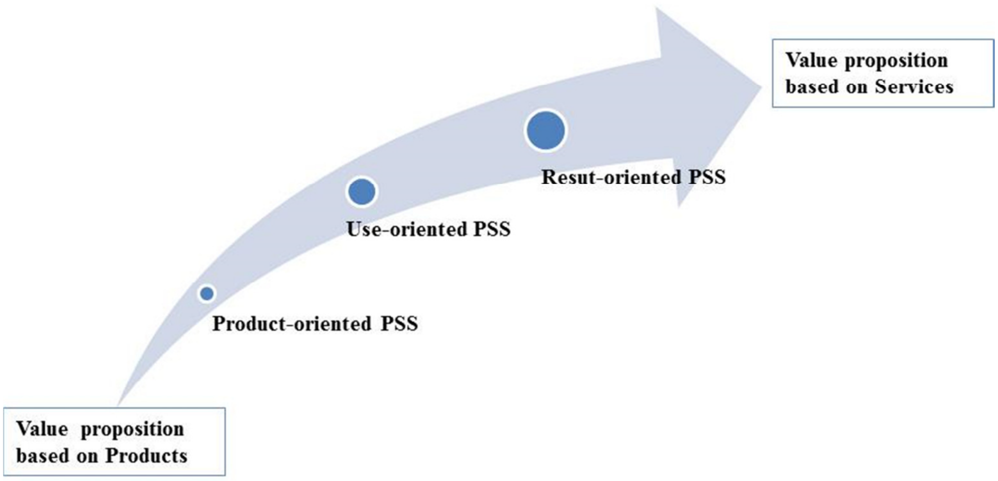

Fig. 6. Value proposition orientation of PSS. Source: adapted by Wang et al. (2011).

PSS is an interdisciplinary field, because it presents interesting and challenging characteristics for many researchers from different research areas. Business Management mostly investigates the bundling of products and services from a marketing perspective, while in the Engineering & Design field the focus is on designing, developing and delivering the PSS to the final user, together with a developing interest from the Information and Communication Technologies (ICT) and Information Systems disciplines, because of the increasingly close relationship between PSS and technology (Annarelli et al., 2016).

Various research projects have been funded by the European Union (EU) and by the United Nations Environment Programme (UNEP) over the past decade with the aim of developing and testing methods and tools for PSS design, such as for example SusHouse, ProSecCo, HiCS, MEPSS, SusProNet, D4S, LeNS, among others (Vezzolli et al, 2015). From the year 1998 onwards major research institutes around de world launched the following PSS related research projects (Orloff and Heinz, 2015; PSS-Cluster, 2017) mainly funded by the EU. In the context H2020 EU vision, there is a specific Cluster of H2020 Research Projects on Product Service Systems, which among them included the following projects already realized or ongoing:

- SusHouse: Strategies towards the Sustainable Household, EU funded 1998-2000 (Vergragt, 2000).
- ProSecCo: ProducteService Co-design, EU funded 2002-2004.
- Innopse: Innovation Studio and Exemplary Developments for Product-service,
- EU fundet 1997-2002 (Bitzer and Biernatzki 2004).

- HiCS: Highly Customerized Solutions, EU funded 2001-2004 (Manzini et al., 2004).
- MEPSS: Methodology for Product Service System development, EU funded 2002-2005 (van Halen et al., 2005).
- SusProNet: Network on sustainable Product-Service System development, EU funded 2002-2005 (Tukker and Tischner, 2006b).
- D4S: Design for Sustainability, a step-by-step approach UNEP funded 2005-2009 (Tischner and Vezzoli, 2009).
- PROTEUS (PROduct/service-system Tools for Ensuring User-oriented Service) is a recently completed innovation consortium, with a deep focus on developing new knowledge about how after-sales service can be effectively integrated into product- and business development, so as to become a source of revenue, rather than a cost to the providing company (Proteus, 2010).
- FALCON: Feedback mechanism Across the Lifecycle for Customer-driven Optimization of iNovative product –service design (Klein et al., 2016).
- LeNS: Learning Network on Sustainability, funded by Asia Link Programme, EuropAid and European Commission, 2007-2010 (Vezzoli et al. 2014)
- Transregio 29: Dynamic Interdependencies between Products and Services in the Production Area, German Research Foundation (DFG) funded 2006- 2011 (Meier, 2013).
- DIVERSITY: a methodology and engineering environment supporting companies in using social media to realize a context sensitive lean design process of product service systems (Neves-Silva et al., 2016).

An analyses sin the scope of most of these projects reveals a clear focus on industrial large companies based in Europe.

4.2.3 PSS: Benefits and barriers

Industries currently faced high competition induced by globalization. Moreover, the traditional production and business models, based on manufacturing and selling products, are reaching some limits due: the natural resource depletion, market saturation, increasing costs, shortening product life times, consumers' needs are looking for more sustainable solutions, the hyperconsummerism and planned obsolescence are seen by the consumer as a problem instead of a vector of growth for the industry, etc. This situation generates structural crises within the manufacturing sector. In this context, enterprises are seeking to develop both profitable and eco-friendly offers without degrading the consumer needs, by adoption of PSS (Doulle et al., 2016).

Add services to a product may also introduce advantages from the producer's perspective, because through the implementation of reuse & recycling policies, many components and parts could be remanufactured, reutilized and recycled into new products, which is clearly more sustainable (economically and environmentally) than producing entirely new components (Annarelli et al., 2016).

Therefore, aiming consolidated the main benefits and barriers for stakeholders/actors in PSS development to the current world economic context, a comprehensive list based in previous studies (Beuren et al., 2013; Cavalieri and Pezzota, 2012; Baines et al.; 2007; Mont, 2002; UNEP, 2001; Ceschin, 2014) is presented (Table 1).

Table 1 - Benefits and barriers for stakeholders in PSS

Benefits	Barriers
Customer	
• Setting barriers to competitors by creating a customer–supplier intimacy and mutual dependence. • Flexible and personalized service; quality and satisfaction. • Continuous improvement of products and services. • More value obtained through more customization and higher quality. • Greater diversity of choices in the market. • Service component, being flexible, can deliver new functionality better to suit customer needs. • Removing administrative or monitoring tasks away from the customer and back to the manufacturer. • Lower costs and problems associated with buying, use, maintenance and eventual replacement of products. • Consumers may more easily learn about environmental features of products and how they can contribute to minimizing the environmental impacts of consumption. • Releasing customers from the responsibilities of asset ownership	• Need of reciprocal trust between provider and customer in shifting from a transactional to a long-term relationship. • Low level of maturity and lack of engagement in the PSS market. • Consumers not enthusiastic about ownerless consumption. • Economic Factors. • Socio-Psychological Factors
Provider	
• Differentiating the market offering, increasing the revenue by offering new services • Customer loyalty and trust innovation by monitoring products in use. • Cost and resources reduction; maximization of results; knowledge created during the development process are sold as consulting and training services; products reused in combination with several different services. • More opportunities for innovation and market development. • Increased operating efficiencies. • More and longer-term client relationships Improved corporate identity. • Better feedback on consumer needs. • The potential to use companies' technical knowledge to find	• Manufacturers concerned with increasing risks due to the adoption of new pricing policies, lack of expertise in designing and delivering services. • Change management of the organization • Relationship with stakeholders along the Value Chain • Relationship with customers • Internal mindset and capabilities

ways to deliver same or better value-in-use while using less energy or materials is said to offer the potential to reduce cost.	
Society and Environment	
• Creating a more sustainable approach to business. • Reduction in consumption through alternative use of product; provider responsible for the products and services through take-back, recycling, and refurbishment-reducing waste throughout the product's life; services planned according to the life cycle of the product. • Public pressure on environmental issues grows. • Increase in the supply of services; new jobs. • Fewer waste management concern for the domestic and manufacturing sector. • More sustainable economy based on high levels of service. • Increased employment. • Through the increase in customization and in service activities, the loss of jobs in traditional manufacturing can be offset.	• Socio-environmental benefits not always significant • Low environmental awareness • Externalities • High cost of labour in industrialised countries

Analyzing the several expected benefits to customer/user, company, society and environment, is possible conclude that PSS have potential to effectively to respond the currents complex competitiveness demand. Nevertheless, some barriers to successful development are complex and of hard management (e.g. the need of reciprocal trust between provider and customer in shifting from a transactional to a long-term relationship and the need change management within company) and can blocking the expected benefits. The next section discuss regarding to sustainable criticism involving PSSs.

4.3 Sustainable Product-Service Systems

For some decades PSS have been known and acknowledged as effective means towards more sustainable production. However, despite several singular initiatives, the PSS have still not been implemented widely. Possible reasons for this failure to disseminate the concept are the lack of inappropriate supporting methods and tools for the companies and the lack of acceptance of consumers. Here we address the former barrier. The development and implementation of eco-efficient PSS is one of the most important company related steps towards sustainable development (Oman, 2003).

The notion of PSS, whereby products are not sold to customers but are provided as part of a service or rental contract, originated in the business world due to perceived business benefits. More recently, it has been recognized that such systems may also have environmental advantages because they facilitate take-back, reuse, and recycling, thus reducing material consumption, energy, emissions, and waste. Hence, the concept of SPSS has gained in usage, especially in Europe, and exemplifies the "service economy" (Ness, 2009).

Sustainability emerged as the principal topic about PSS from its start until present day but is losing its main role among research fields, though it does remain important. From an extensive literature review in 342 studies Annarelli et al. (2016) conclude that, even though PSS started its development linked to sustainability and environmental aspects, nowadays, these are no longer the most influent aspects of this research stream. Indeed, especially in sharing economy and collaborative consumption models, customer acceptance is one of the main concerns because of the important shift operated in consumption schemes focused on usage rather than on possession.

To highlight the need of these deep changes to SPSS diffusion, Table 2 seeks to highlight the key operational aspects of SPSS, in comparison to reverse supply chain utilization represented by product stewardship, recycling and take-back (Ness, 2009).

Table 2 - Comparison between SPSS and traditional product stewardship

SPSS	Product stewardship/recycling/take-back
• Ownership of product retained by service provider	• Ownership transferred to customer
• Holistic management of suite of services by "solution provider" for customer leading to improved service for customer	• Not normally as responsibility passes to customer with sale/purchase
• Ease of technological updating by provider for customer	• Updating requires purchase of new equipment and disposal
• Provider manages fleet of products for customer, leading to increased utilization, reduction in fleet, and efficiencies	• Not normally
• Reporting by provider on performance of fleet in meeting service outcomes	• Not normally. Performance is related to levels of collection, recycling and resource recovery, at industry level
• Payment can be related to performance	• Not normally
• Partnership between provider and customer opens up opportunities for other profit centres/increased business	• Not normally
• Almost certain that product will be taken back and greater chance of reuse/recycling	• Depends on consumers depositing used equipment at collection points (even if free)
• Provider has incentive to design product and components in robust, modular, standardized form for ease of disassembly and enabling longevity	• Some incentive due to take-back and recycling
• Customer pays stream of payments, not large capital cost up front	• No

• Employment generation including remanufacturing, services	• Some employment generation in collection, sorting, disassembly, recycling, etc.
• Less resource use (materials, energy, water) and emissions, waste due to products being kept in closed loop - reduced/reused resources	• Recycling uses more energy than reuse

Compared to the traditional product sales model, within an SPSS model a company can improve revenues if it can meet the same demand by providing a less resource-intensive product and related service mix. Cost savings for the producer/service-provider result from reduced quantities of product materials, streamlined managerial costs and reduced costs from prolonged responsibility for the product, throughout its use and disposal (Vezzoli et al., 2015).

4.3.1 SPSS: benefits and barriers

SPSS carry great potential to deliver social well-being and economic prosperity while operating within the limits of our planet. They can however be complex to design, test, implement and bring to the mainstream (Vezzoli et al., 2015). PSS allows firms to de-couple economic growth from environmental pressure while satisfying consumers' needs, constituting an important strategic market opportunity (Annarelli et al., 2016).

The sustainability goal can be reached through PSS in different ways: reuse and recycling of products at the end of their life cycle, which is a concept that can be applied to several business models, like office furniture, construction machinery industry, manufacturing, maintenance services to lengthen products' useful life and reduce change rate, a potential that can be fully exploited in manufacturing forms of leasing, sharing and/or pooling in order to maximize consumption rate by allowing multiple use, leaving to the provider the ownership and maintenance of the product (Annarelli et al., 2016).

However, despite several singular initiatives, PSS have still not been implemented widely. Developing and implementing PSS which are successful in the sense of positive impacts on sustainable development present a challenge to companies. This challenge becomes manifest in a process, during which obstacles and trade-offs between different sustainability targets may appear (Oman, 2003).

In this same direction, recently Pigosso and McAloone (2016) said that, despite their substantial potential for enabling increased environmental performance, PSSs are not intrinsically environmentally sustainable. Several studies have demonstrated that PSS business models in certain cases may have a negative effect on the environment and only result in economic benefits (Barquet et al., 2016a; Tukker, 2015; Doualle et al., 2015). Boucher et al. (2016, p. 1) corroborated: "The PSS concept was initially considered to be a promising initiative to influence on sustainable production and consumption patterns. But it is now stated that PSS do not necessarily lead to sustainable solutions". Consequently, abroad this discussion, a perspective defined as "Sustainable Product-Service Systems (SPSS)" has received attention from academy. In the SPSS view, the PSS need be developed in a Triple Bottom Line perspective of sustainability, balancing the economic, environmental and social factor simultaneously (Maxwell and van der Vorst, 2003).

A comprehensive relation of potential SPSS benefits and barriers is presented (Tukker and Tischner, 2006; Pigosso et al., 2010; Vezzoli et al., 2015; UNEP, 2002; Ceschin, 2013):

Table 3 - Benefits and barriers to stakeholders in SPSS

Benefits	**Barriers**
Customers	
• The benefits for the customer/user arise from the fact that S.PSSs cut initial investment and running costs. The benefits that accrue are not only economic, but also more widely socio-ethical, as SPSSs can broaden access to useful goods and services to lower income strata. • SPSS is seen to provide value through more customisation and higher quality. The service component, being flexible, can also deliver new functionality better suited to customer needs and is often described as removing administrative or monitoring tasks away from the customer and back to the manufacturer. • B2B customers tend to outsource secondary tasks at any rate, and here they can concentrate on their core competences. • Individual users (in business-to-consumer sectors, B2C) are also freed from the burden of responsibilities that do not relate to satisfying the particular need in question. For example, they are freed from caring about washing machine maintenance and end-of-life procedures, when the need is to have clean clothes. • Higher level of productivity because of better use of the product's performance and the longer operation possibility. For most SPSS cases, the customer receives value in a form that is close to current need and/or want ("unit of satisfaction"). • Costs reduction • Reduction of problems associated with the purchase, use, maintenance and eventual replacement of products. • Service provider is stimulated to use and maintain equipment properly, increasing both efficiency and effectiveness.	• Customer acceptance
Provider	
• More durable products, diminishing the total stock of product required in the cycle to meet a specific need at any given time. • Renting potentially opens up the possibility for more intensive use of the product, with the same environmentally beneficial outcome. • Manufactures may take more professional care of the product over the use phase, thus ensuring a higher quality end-stock and less downcycling. • Manufacturers, which are also the main operators of the PSS, will have no incentive to sell excess material, will be in a better position to optimize the products	• Require a change in the routine behaviours.

to their true function, and will have far better knowledge about the true requirements and characteristics of the equipment. • Lower materials and energy consumption during the phases of production and use of services compared with products. • Lower stock of products in manufacturing, since it encourages leaner manufacturing because products are more valuable. • Extension of the manufacturer's responsibility for the product, making it more palatable to the consumer, manufacturer and environment. • Manufacturers encouraged developing innovative uses for end-of-life products. • During the use phase, the producer has a potential economic interest to reduce the amount of resources consumed, because profit is dependent on the cost per unit of service provided to the customer. • Easier upgrading to more eco-efficient technologies. • Since the producer/provider remains the 'owner', or at least retains some responsibility for the product over its life cycle, there is an economic incentive to extend the product's lifetime. In this way, the producer, in essence, postpones both the disposal costs and the costs of manufacturing a new product. • At the end of the product's life, the producer has the potential economic interest to re-use or re-manufacture components to save on landfilling costs and new component manufacturing. • By focusing on the utility delivered from a product e service mix, the company frees the client from the costs and problems associated in the acquisition, use, maintenance and disposal of equipment and products. • The producer will be economically motivated to look into other ways to extend material life, such as by updating, repairing, remanufacturing, recycling, energy recovery or composting. • The SPSS benefits for companies result from improved strategic positioning which is tied to the potential added value perceived by clients. • Attend the of legislation threats. • Response to client's wishes. • Move towards green purchasing by authorities. • Fewer waste management concerns from the domestic and manufacturing sector, companies considering themselves environmentally and socially responsible. • More sustainable economy based on higher levels of services.	
Society and Environment	
• Collection of end-of-life products will be significantly easier, thus increasing the rate of utilization of end-of-life products. • Development of better end-of-life disposal processes, since there will be clear pressure to design for this stage of the product life-cycle, starting from the concept generation phase onwards; • Potential for environmental benefits through economies of scale. • SPSS are focused on access rather than ownership: they lower or allow users to avoid the initial investment (e.g. people with low incomes do not need to purchase a solar panel outright) as well as the running costs (e.g. if the solar panel breaks accidentally there is no direct cost for repair). • SPSS are more focused on the context of use, because they do not only sell products: they open (and/or lengthen) relationships with the end user. This should trigger a greater involvement of (more competent) local, rather than global, stakeholders, thus fostering and facilitating the reinforcement and prosperity of the local economy. • Since SPSSs are more labour and relationship intensive, they can also lead to an increase in local employment and a consequent dissemination of skills. • Increased employment and provide jobs for local markets.	• Involves significant corporate, cultural and regulatory barriers. • Require a change in the routine behaviours.

Fundamentally the contribution of PSS to sustainability is based on four different types of motivation (Pigosso et al., 2010): (i) Economic: there is little profit in selling machines, but more profit in delivering services; (ii) Technical: the equal focus on product and service development enables innovation; (iii) Social: integration of product and service engineering enables high-income countries to protect and build up employment; while countries with low technical qualifications improve their performance levels; (iv) Ecological: PSS reduce the consumption of resources.

Considering still the three PSS categories, it can contribute differently to the environment issues (Tukker, 2004; Pigosso et al., 2010). Product-related service, advice and consultancy, and product lease have probably marginal environmental benefits, since at best mainly incremental change such as better maintenance etc. can be expected. Cases of product leases may even have negative environmental effects if the lessee feels encouraged to use the product less carefully than if he owned it.

- Renting, sharing or pooling can have major environmental benefits if the burden is related to the production of the artifact, since the same product is shared and used more intensively. However, if, in the case of product renting or sharing, the use phase dominates and does not lead to a low use behavior there is little positive outcome. In such cases, pooling leads to lower impacts since more people make use of the product at the same time.
- Activity management/outsourcing PSS will lead to lower environmental impacts if (monetary) efficiency gains are related particularly to materials and artifacts, and not to human time inputs.
- The pay per unit use overcomes the split incentive between production costs of a product and costs incurred in the use phase. It is likely that at least incremental gains will be obtained, but since the technological system in principle does not change radically, no significant improvements can be expected.
- In theory, functional result PSSs have the highest potential since the provider offers a result closer to a final client’s needs and therefore has greater freedom to design a low-impact system.

For use-oriented and result-oriented PSS types, manufacturers keep the ownership of products and deliver utility or a result. The focus of customers and manufacturers is shifted from the product itself to the functionality of products and the quality of services in the product usage phase. The common benefits of these two types of PSS following (Yang et al., 2015):

- *Increased resource and energy efficiency in use.* In most situations, both customers and manufactures have the incentive to increase resource and energy efficiency in the use phase of products. Customers pay per use or per service unit, so increasing efficiency in use will reduce the total cost. If manufacturers are the owners or even users (in result-oriented PSS) of products, they are incentivised to use products as efficiently as possible in terms of materials and energy in order to reduce costs.

- *Increased recycling, remanufacturing and reuse*. Use-and result-oriented PSSs have the potential to increase the reuse of products at their end of life by recycling, reconditioning and remanufacturing. They also can increase customers' acceptance of remanufactured products since customers do not own the products and care less about how new the products are. Moreover, manufacturers find it easier to collect used products as they can more easily predict the timing and quantity of returns. Also incentivise firms to reuse parts as much as possible at the end of the product life cycle to improve remanufacturing technology and design for remanufacturing.
- *Increased product usage.* Providers own products and therefore have incentive to maximise product use (to ensure that products are used as intensively as possible). This affects positively sustainability.
- *Dematerialisation.* Enables a total reduction in the use of materials, energy and products because the same number of products can meet the needs of more people.
- *Reduced ownership responsibility for customers.* Customers are released from the responsibilities of owning products, reducing the burden of caring in some situations.

The report "Green Servicizing" for a More Sustainable US Economy" from US Environmental Protection Agency (EPA, 2009) discussed key concepts and tools and also propose a set of innovative green strategies to improve eco-efficiency in each PSS category (Table 4, 5, 6).

Table 4 - Innovative Green strategies to improve eco-efficiency in Product-oriented PSS

Subcategory	Innovative Green strategies to improve eco-efficiency
Product-related services. In addition to direct sale of the product, the provider offers services related to the use phase: e.g. maintenance, extended warantees, financing, supply of consumables, take-back, etc.	Environmental performance mechanisms primariliy exist unders three variants of product-related services. **Product take-back models.** The primary value-added service in these models is product take-back at end-of-life (or once the customer no longer requires the product.). Thus, these models are expected to lead to increased re-use and material recovery. **Recycling/remanufacturing-based businesses**

	While not PSSs according to some definitions, we include them in this category as they add services to the end-of-life phase of a product, and thereby change its final disposition. These businesses recover not products at end of life, but waste material, from which they create new products. Expected environmental benefits are reduced demand for virgin materials and reduced disposal impacts. **Product life extension** The primary value-added services in these models are maintenance and upgrades, both of which should extend product lifetime. This reduces the total number of products over time, thus reducing all impacts in phases prior to use (e.g., extraction, manufacturing), as well as reducing disposal impacts
Product-related advice/consultancy. In addition to direct sale of the product, the provider offers advice or consultancy on the most efficient use of the product, which may extend to logistics systems and management structures	"Efficiency consultancy" has the potential to reduce the in-use impacts of the product (e.g. energy consumption) and, potentially, to extend product lifetime.

Table 5 - Innovative Green strategies to improve eco-efficiency in Use-oriented PSS

Subcategory	Innovative Green strategies to improve eco-efficiency
Product lease (Individual lease or rental). Models in this category offer the customer exclusive (i.e., individual) use of a rented or leased product over the lease or rental term. Maintenance and repair responsibilities generally lie with the provider. Examples include long-term leases for e.g., IT equipment, vehicle and capital equipment.	These models place end-of-life responsibility for the product on the provider and also should place a premium on product durability and maintainability. Thus, these models may provide incentives to producers to pursue Design for Environment (DfE) approaches, creating more durable products with increased proportions of recyclable/reusable parts. As a result, environmental loads prior to the use phase (e.g. virgin materials inputs, energy consumption associated with production) may be reduced. In addition, as ownership remains with the provider, proper disposal and/or improved recovery may be more likely. (However, this is not the case when products are disposed by sale to secondary markets.)
Joint use (Sequential and pooled). Joint use models offer product rental or leasing in such a way that a number of individual customers use the same product. This joint use may be simultaneous or, when the rental period is short, sequential. Maintenance and repair responsibilities generally lie with the provider. Traditional car rental and car-sharing both fall in this category. The short rental period of car-sharing and the concept that cars stations are "shared" among users in the vicinity mean that car-sharing is a "pooled use" model; traditional car rental is a sequential use model.	In addition to the potential benefits under "individual lease or rental" enumerated above, these models should reduce the total number of products required to deliver a given level of economic function. Thus, they may further reduce all impacts in phases prior to use (e.g., extraction, manufacturing), as well as further reducing disposal impacts.
Pay-per-service unit. In Pay-per-service-unit models, the customer pays for the output of a product on a per-unit basis. In contrast to "functional result" models (below), the user is responsible for operation of the equipment. "Well-known examples include the pay-per-print formuls	In addition to the potential benefits under "individual lease or rental" enumerated above, these models can provide a clear, utilization-based price signal to the user, which may stimulate conservation behaviors, reducing the utilization of the product and attendant use-phase environmental impacts.

now adopted by most copier producers. In this formula, the copier producer" (Tukker et al 2006a)	

Table 6 - Innovative Green strategies to improve eco-efficiency in Results-oriented PSS

Subcategory	**Innovative Green strategies to improve eco-efficiency**
Activity Management/Outsourcing. In these models, the provider undertakes responsibility for a service that a customer would otherwise undertake in-house, with its own employees. Examples include outsourcing of cleaning, mailroom, or customer-service functions.	As Tukker et al. (2006a, 34) note "in many cases, the way in which the activity is performed does not shift dramatically" [compared to how the customer would perform the function in-house].Potential environmental benefits arise when the provider realizes cost savings and efficiency gains in material and energy inputs, not via the utilization of lower-priced labor (Tukker et al. 2006b).
Functional results. Tukker et al. (2006) characterize functional results models as those in which the provider is engaged to deliver a result, without reference to a specific technological system (i.e., the means of delivering the result are at the provider's discretion.). Examples cited include Integrated Pest Management (IPM) services, in which IPM providers promise to keep farmer's losses to an agreed minimum rather than selling pesticides. In reality, however, this may be a difficult standard to meet; results provision is rarely fully detached from a specific technological system.	In addition to this general situation, we identify two types of models, spanning both the Activity Management and Functional results categories, in which environmental performance improvements are most likely to arise: **IT Dematerialization** IT dematerialization models utilize information technology to deliver a function to a customer in such a way as to substantially eliminate the need for the products and services that deliver this function under business. Examples include Video conference and tele-presence systems (in principal reducing the need for travel) and e-learning (in principal reducing the need for travel and instruction facilities). Benefits arise when the IT-based approach indeed reduces material and energy intensity compared to physical presence. **Performance-based "functional procurement"** Performance-based services provide functions such as chemical management, waste management, energy services, and logistics management (3PL). In these services, traditional compensation mechanisms (e.g., fees per ton waste hauled, per BTU used) are replaced by performance-based compensation mechanisms that give the service provider incentive to reduce the customer's generation of waste, their use of energy, or consumption of other environmentally problematic goods or services. This category includes "efficiency services," which may not have a clear product associated with them, but do alter the utilization of products and infrastructure (e.g., ESCOs, 3rd Party Logistics).

The PSS categories by US Environmental Protection Agency according to Baines et al. (2007), Tukker, 2004, Tran and Park (2014) classification, summarize the categories in light of environmental factors in the following manner:

- *Product-oriented*. The company sells a product with additional services to ensure the working condition of the product. The ownership of the product is transferred to the customer. In this case the product is already available and service can be considered as an "additional value" to the product. Examples of services are: advice and and consultancy, maintenance, repair, recycling, refilling, etc. PSSs in this category are dominantly geared towards the sale of products, but added services are a source of additional value. These services include, e.g., extended warranties, maintenance, upgrading and end-of-life management. Product ownership lies with the consumer.

- *Use-oriented*. The company sells the use or availability of a product not owned by the customer. Depending on the portions of product and service, this type of PSS can resemble a product oriented PSS or a result oriented PSS at a certain level. A use oriented PSS can be considered as the most "general" type of PSS while a product oriented PSS and a result oriented PSS can be considered as "extreme" types of PSSs (when one component–either product or service – has the dominant portion compared with the other). Examples: product leasing or sharing.
- *Result-oriented*. The company sells a result or capability of a product not owned by the customer. The final outcome or "value" is what the customer wants to achieve. In this case, the decision of what kind of service to deliver to the customer is essential and the product can be considered as a "means" to realizing the service. For example, instead of selling paint to a customer, the company can sell the result, a painted house.

In general, compared to a traditional product sales offer, a SPSS it is in the economic and competitive interest of the producer/provider to foster continuous innovation in reducing the environmental impacts and improving social equity and cohesion (Vezzoli et al., 2015). Furthermore, the discussion about sustainable services or sustainable product–service systems tends to emphasize the eco-efficiency perspective, rather than explicitly capture all sustainability aspects. Social or socioeconomic considerations are often forgotten or by-passed without scrutiny (Halme et al., 2004).

Ness (2009) affirm that SPSS has the potential not just for greening of business but also for achieving economic development, improving the lives of the poor and contributing towards achievement of the UN Millennium Development Goals (see http://www.un.org/millenniumgoals/goals.html). Thus, SPSS innovations represent a promising approach to sustainability. However its adoption is still very limited because it often involves significant corporate, cultural and regulatory barriers (Ceschin, 2013).

Ceschin (2013) stated that eco-efficient PSS innovations usually encounter the opposition of the existing socio-technical context, because in most of the cases they require a change in the routine behaviours that are daily reproduced by individuals, groups, business communities, governmental institutions and society at large (Tukker and Tischner, 2006c). As a result, eco-efficient PSS innovations are often immature when they enter the market and therefore have high probability not to survive under the mainstream selection environment. Thus, since the diffusion of SPSSs requires changes in contextual factors conditions, a much broader system approach is therefore needed to facilitate the societal embedding of this kind of radical innovations (Ceschin, 2013).

To capture their full potential, SPSS may require reconfiguring with products being designed - in standardized, modular form - for ease of reuse, disassembly and recycling via remanufacturing. Energy will be saved where products or their components can be reused in as close as possible to the original form, reflecting the 3R (Reduce, Reuse and Recycle) approach (Ness, 2009). To develop a business model oriented to sustainability, sustainability aspects should already be taken into account at the planning stages, when strategies, ideas, opportunities and concepts are identified and created. However, there is a lack of methods to assist the creation of sustainable business models (Barquet et al., 2016b).

Regarding the ideation and development of SPSS, Ceschin (2014) stated the need to moving from product thinking to system thinking vision. This new design attitude can be articulated as follows: (i) a satisfaction-system approach is required: the starting point is the satisfaction of a particular customer demand; (ii) a stakeholder configuration approach is required: the design approach should focus on designing not only the combination of products and services, but also the stakeholder network configuration required to produce and deliver the PSS offer; (iii) a customer-oriented approach is required: the relationship between the customer and the actors producing and delivering the PSS plays a key role in the design of an effective PSS. The early involvement of customer is essential; (iv) a system sustainability approach is required: it is crucial to appropriately design the stakeholder network configuration (offer model) in order to make stakeholders economically incentivised in improving the environmental and socio-ethical performance of the PSS.

To mitigate the difficult to implement SPSS, according to Ceschin (2013, p. 86) “a relevant research direction is to understand how to translate these factors and indications into an instrumental step-by-step approach (and related tools, guidelines etc.), to be used by companies, project managers and management consultants to design, manage and orient the process of introduction and diffusion of this kind of innovations". Finally, in the current economic and social crises, we are facing rising prices, unstable supply chains, global food crises, inflation, recession, rising unemployment, credit crises and citizens' lack of confidence in government, the financial system and in many other societal institutions. These crises can and must be transformed into opportunities and the current challenging and ever-changing context can help drive the change (Vezzoli et al., 2015).

4.4 Research method

The main objective of this research is obtain a better understanding abroad the discussion on sustainable aspects of PSS investigating if really the PSS concept differ of SPSS approach. Based on the proposition that there is an emergent discussion being addressed in literature by different tow research communities, this review seeks to obtain a more detailed understanding of knowledge production both within and across them.

In order to clarify this current discussion of literature and drive new researches avenues to PSS field, the present study adopted a systematic literature review. One of principal advantages of systematic literature review is provides understanding of the state of the art of the research domain and aids in the identification of useful knowledge (Dresch et al., 2015; Tranfield and Denyer, 2003). Systematic review differs from a traditional general review in that it adopts a replicable, scientific, and transparent process. This leads to developing collective insights based on theoretical synthesis of existing studies. Previous researchers have argued that using such an approach to review literature can ensure that bias is limited, chance effects are reduced, and the legitimacy of data analysis is enhanced (Cook et al., 1997; Reim et al., 2015). In this sense, we adopted the research protocol suggested by Dresch et al. (2015) and have detailed the structured stages adopted as following.

Step 1: Planning research process. *Definition of the issue and conceptual framework*. Our research aims to comprehend if PSS and SPSS are independent concepts and identify the factors that explain the prevalence of these different research streams between academic of service field. *The research question*. The research question of this study is, PSS and SPSS are really two different concepts?

Work team. The stages of systematic literature review process were performed by the authors of this study.

Step 2: Identifying publications and applying practical screening. *Search strategy, keywords, period, databases, inclusion/exclusion criteria and eligibility/coding.* For made the choice of the keywords and Boolean operator's definition, initially a preliminary analysis was performed in previous systematic literature review papers focused in PSS domain. A initial list of keywords was extracted from following papers: *'State-of-the-art of design, evaluation, and operation methodologies in product service systems'* by Qu et al. (2016), *'Product e Service Systems (PSS) business models and tactics - a systematic literature review'* by Reim et al. (2015), and the *'Product-service systems: a literature review on integrated products and services'* (Beuren et al., 2013) and '*State-of-the-art in product-service systems'* (Baines et al., 2007). As result, an initial set of keywords frequently used by academics in PSS domain was consolidating (Table 2).

Table 7: Keywords combination and search results

Keyowrds	Total in Scopus				Total in WoS			
	literature review	systematic review	state of the art	review	literature review	systematic review	state of the art	review
Sustainable product-service system								
Product-service system	8	2	8	17	3	1	2	5
Product-service	11	2	9	23	9	1	7	17
Servitization	2		1	4				2
Sustainable service		1		2		1		1
Industrial product service system		1		1				
Service engineering			3				1	
PSS	4	1	5	20	4	4		15
IPSS								
SPSS				11	2	3		23
Service-dominant logic				1				
Servicification								
Functional product				2				2
Product service engineering								
Product service offering	1			1				
Functional sales								
Functional economy				6				
Service-based products								
Service based business	5	4	2	8				
Service providing		1		27				
Sustainability contribution								
Dematerialisation				1				
Leasing								5
Service infusion	1			1				1
Product-to-service								
Service operation		1			1	1		5
Product-related services								
Service integration				4				1
Value bundle								
Covalent product								
Integrated solutions				1				
Service science	1			3				
Service economy				1				1
Servicification post mass production paradigm								
Post mass production paradigm								
Service-oriented	2	7	7	19	1	5		15
Integrated solutions			1	1				
Product bundling								
Hybrid offerings								
Hybrid product								
Hybrid value		1		1				
Hybrid bundle								
Sharing economy				2				1
Shared economy								
Circular economy	1			7	1			7
Total	**36**	**21**	**36**	**164**	**21**	**16**	**10**	**101**

Next, the search process was conducted in the field “Title” in Scopus and WoS databases combining these related keywords with the following keywords: “literature review, systematic review, state of the art, review”. We decide use WoS and Scopus because their coverage differ the most in Engineering, Natural Science and Arts/Humanities and not necessarily index the same journals (Mongeon and Hus, 2016). Scopus database is one of the largest multidisciplinary including social science and engineering studies, abstract and citation databases of peer-reviewed literature. Its covers research from several publishers (i.e. Elsevier, Emerald, Springer, and Wiley, among others). Because these databases cover peer-reviewed multidisciplinary research studies, it was certain to find a good number of studies (Reim et al., 2015).

This choice of studies based on literature review was observed for two reasons. The first reason is because this type of work cover a wide research period, and this aspect turn easier captures discussion of evolution of PSS studies and the recent research streams on SPSS and others communities within service field. The second reason is because generally review papers propose a qualitative mapping of research trends or the classification of existent background in structured categories to better conduce the analysis of literature background. The analyses of these classifications enable a better comprehension on PSS and SPSS research streams. Thus, these aspects are aligned with the research objective of this work. In this sense, to exemplify, one of several combinations performed in both WoS and Scopus during the screening process, was the following: 'Sustainable Product-Service System' & 'literature review'.

Step 3: Applying theoretical screening criteria. *Search period.* The search period considered was between January/1995 and December/2016. The In this stage, a structured search process (Fig. 1.) adopted according to Moher et al. (2009) was conducted. *Inclusion and exclusion criteria*. The eligibility criteria adopted for inclusion of studies for full analysis were the following: (i) theorical papers discussing convergences and divergences between PSS and SPSS; (ii) papers investigating the transition process to PSS and SPSS based on empirical analyses; (iii) longitudinal and conceptual papers as based on literature review method; (iv) studies in English language; (v) peer review studies was a inclusion criteria considered for all previous criteria. According to Mongeon and Hus (2016) English has a dominant position in sciences and is overrepresented in the scientific knowledge. Furthermore, the *exclusion criteria* adopted were: (i) studies with high quantitative or statistical bias making it difficult capture qualitative insights; (ii) we used only formal literature, does not including books, 'grey' research reports, etc (iii) studies demonstrating low methodical rigor.

Step 4: Final filtering and process analysis. The data collected from each study were used to identify relevant aspects related to PSS and SPSS trajectory, similarities and differences. Initially, to perform the analysis of selected studies, an open coding content analysis technique was employed aiming certified if the publication stablishes the discussion on PSS and SPSS. Duplicated studies and also papers filtered by inclusion and exclusion criteria were excluded. A relative number of studies were excluded for three principal reasons: are duplicate, are from areas not related with service management field such as clinical/diseases, software engineering or computer science and because they exhibited only a weak link to the focus of our discussion. Finally, the search yielded 38 select studies to content analysis (Apendix I). During the process analysis developing, notes and headings were synthetized in a spread sheet in association with our research question. Thus, after presenting the main metadata results and descriptive analyses, the synthesis based on configurative analyses (Gough, Oliver and Thomas, 2012) was considered and is in depth discussed in the next sections.

4.4.1 Descriptive results

This section begins with the main metadata results of the systematic review. A set of tables was elaborate exemplifying the total of published articles and the respective matching keywords searched individually in the field title, abstract and keyword in Scopus (status in 28/fev/2017). We exemplify the results from Scopus to avoid duplication of studies between databases. Thus, next results explored the finding of descriptive analyses to PSS and SPSS.

Table 8: Evolution of publications

Year	'product-service system'	'sustainable product-service system'
2000	1	1
2001	5	2
2002	3	
2003	12	2
2004	7	1
2005	10	
2006	28	3
2007	24	
2008	30	2
2009	71	
2010	91	3
2011	111	
2012	118	4
2013	163	4
2014	191	5
2015	237	18
2016	220	13
Total	**1322**	**58**

By analysis in Table 8 relevant findings emerge. First, is possible verified an increasing number of published studies from 2010 regarding 'product-service system' field. In addition, this interest can be considered recent because around 85% studies in of PSS were published from 2010. The number of publications doubled from 2011 to 2015. Furthermore, a very recent increase interest by 'sustainable product-service system' topic is past two years is noted. Regarding the total number of studies (58), still is possible affirm that the literature available is very limited.

Table 9: Number of publications in 'product-service system' per source

	Source	Total
1	Journal Of Cleaner Production	72
2	IFIP Advances In Information And Communication Technology	51
3	Proceedings Of The International Conference On Engineering Design Iced	40
4	CIRP Journal Of Manufacturing Science And Technology	23
5	Proceedings Of The ASME Design Engineering Technical Conference	23
6	Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	22
7	Journal Of Manufacturing Technology Management	21
8	International Journal Of Production Research	20
9	Jisuanji Jicheng Zhizao Xitong Computer Integrated Manufacturing Systems CIMS	17
10	International Journal Of Advanced Manufacturing Technology	15
11	Computers In Industry	14
12	CIRP Annals Manufacturing Technology	12
13	Lecture Notes In Business Information Processing	10
14	Proceedings Of The Institution Of Mechanical Engineers Part B Journal Of Engineering Manufacture	10
15	International Journal Of Computer Integrated Manufacturing	9

Tables 9-12 give the numbers of papers by author, affiliation, country and journal on these research streams. The Journal of Cleaner Production is the dominant source Journal in both ‘product-service system’ and ‘sustainable product-service system’ field. CIRP Journal of Manufacturing Science and Technology also is well ranking Journal in both fields.

Table 10: Number of publications in ‘sustainable product-service system’ per source

	Source	Total
1	Journal Of Cleaner Production	14
2	CIRP Journal Of Manufacturing Science And Technology	3
3	Springerbriefs In Applied Sciences And Technology	2
4	Corporate Social Responsibility And Environmental Management	1
5	Design Principles And Practices	1
6	Ecological Economics	1
7	Environmental Innovation And Societal Transitions	1
8	European Journal Of Engineering Education	1
9	European Journal Of Operational Research	1
10	Futures	1
11	IEEE Transactions On Engineering Management	1
12	IFIP Advances In Information And Communication Technology	1
13	International Journal Of Agile Systems And Management	1
14	International Journal Of Life Cycle Assessment	1
15	International Journal Of Sustainability In Higher Education	1

The comparative list of top 15 authors ranked by number of publications (Table 9) suggests interesting findings. First, despite it is reasonable to have as a prior expectation to find the same authors’ name research presents in the two topics, only two authors, Fabrizio Ceschin and Xavier Boucher, demonstrate researches in both traditional PSS and SPSS domain. Nonetheless, it is important stat that a more complete list, beyond the 15 names could give complementary analysis. The comparative list of authors with most publications contains some well-known names in PSS field. Such as for example, Prof. Yoshiki Shimomura (Tokyo Metropolitan University), Prof. Tomohiko Sakao (Linköping University), Prof. Giuditta Pezzotta (Universita degli Studi di Bergamo), Prof. Rajkumar Roy (Cranfield University), Prof. Fabrizio Ceschin (Brunel University London), Prof. Carlo Vezzoli (Politecnico di Milano) among others.

Table 11: Number of publications and citations by author in PSS and SPSS

	'product-service system'				'sustainable product-service system'			
	Author	**Publications**	**Citations**	**Rate**	**Author**	**Publications**	**Citations**	**Rate**
1	Shimomura, Y.	32	236	7	Ceschin, F.	7	113	16
2	Sakao, T.	29	266	9	Vezzoli, C.	6	275	46
3	Pezzotta, G.	23	161	7	Sousa-Zomer, T.T.	4	7	2
4	Roy, R.	22	1298	59	Cauchick M. P.A.	3	7	2
5	Peruzzini, M.	18	173	10	Brissaud, D.	3	0	0
6	Kimita, K.	17	87	5	Diehl, J.C.	3	43	14
7	Meier, H.	17	456	27	Barquet, A.P.	2	0	0
8	Ceschin, F.	16	143	9	Bhamra, R.	2	22	11
9	Lindahl, M.	16	150	9	Bhamra, T.	2	22	11
10	Mörtl, M.	16	12	1	Boucher, X.	2	0	0
11	Boucher, X.	15	23	2	Gnoni, M.G.	2	0	0
12	Germani, M.	15	72	5	Knot, M.	2	24	12
13	Kim, Y.S.	15	69	4	Kohtala, C.	2	38	19
14	Abramovici, M.	14	38	3	Lelah, A.	2	0	0
15	Durugbo, C.	14	117	8	Luiten, H.	2	0	0

Another interesting outcome is regarding the number of citations. The column 'Rate' was calculated dividing 'Citations' by 'Publications' column. This index expresses a global average of citations per publication to each author. Results from 'product-service system' string shows some authors with higher number of total publications, not necessarily get higher total citations index. The highlighted rate to authors Rajkumar Roy and Horst Meier can be partially explained because co-authored the paper entitled '*Industrial Product-Service systems-IPS2'* (Meier, Roy, Seliger, 2010) with expressive 338 citations and Rajkumar co-authored the seminal *'State-of-the-art in product service-systems*' (Baines et al., 2007) with 651 citations. Also is highlighted the first authors in paper '*Product-service systems engineering: State of the art and research challenges*' (Pezzotta and Cavaieri, 2012) with 97 citations and the co-authored '*Modeling design objects in CAD system for Service/Product Engineering*' (Sakao et al., 2009) totalizing 66 citations.

Regarding to 'sustainable product-service system' results, clearly Fabrizio Ceschin and Carlo Vezzoli leads the publications and citations ranking. Vezzoli co-authored the paper '*A strategic design approach to develop sustainable product service systems: Examples taken from the 'environmentally friendly innovation' Italian prize*' (Manzini and Vezzoli, 2003a) with 230 citations. Considering all listed authors, is possible concluded that the lower overall citations in SPSS is mainly explained due fact the interest has been increase in past two years. Thus, is expected that the lead a certain time to the academics develop and conclude their researches, the peer review lead time of papers' submission, plus the recent interest, may affect the performance of citations.

Table 12: Overall publications and citations by author in different fields

	Author	Publications	Citations	Author	Publications	Citations
1	Roy, R.	176	2703	Brissaud, D.	111	914
2	Shimomura, Y.	153	1449	Cauchick M. P.A.	93	760
3	Meier, H.	112	954	Vezzoli, C.	21	522
4	Sakao, T.	84	822	Bhamra, T.	45	413
5	Germani, M.	185	438	Gnoni, M.G.	56	228
6	Lindahl, M.	46	307	Bhamra, R.	8	185
7	Durugbo, C.	50	231	Lelah, A.	26	173
8	Pezzotta, G.	33	189	Boucher, X.	61	160
9	Peruzzini, M.	75	174	Diehl, J.C.	25	149
10	Boucher, X.	61	160	Ceschin, F.	17	143
11	Ceschin, F.	17	143	Knot, M.	25	155
12	Kim, Y.S.	69	137	Barquet, A.P.	10	83
13	Kimita, K.	49	126	Kohtala, C.	6	60
14	Abramovici, M.	49	109	Luiten, H.	2	24
15	Mörtl, M.	30	19	Sousa-Zomer, T.T.	5	1

Final insights emerges by comparative analysis between Table 10 and Table11 that shows the Citations and Publication by author considering all research studies/topics published along their academic trajectory. Considering a specific academic, and calculating for example the division between the values of the column Publications (Table 11) related with 'product-service system' and 'sustainable product-service system' by the column Publications from Table 12 it is possible estimate that authors concentrates their trajectory academic in each topic, and also the opposite. For example, results suggest that PSS is the dominant research focus to the researchers Pezzotta and Mörtl. In contrast, less dominant orientation to PSS field appear be given by Meier and Germani. Considering the SPSS domain, results shows that the research efforts by Ceschin, Vezzoli, Sousa-Zomer and Kohtala are oriented to this field. On the whole, also is necessary consider the direction and vigour of the various knowledge flows and its dissemination might also be influenced by the reputation of the chosen channel for disseminating research output such as the option in favour of the higher ranked journals and impactful index (Lightfoot et al., 2013).

The comparison of publications by affiliation and country (Table 13-14) corroborated similar previous findings in the literature. Cranfield University with its

Innovative Manufacturing Research Centre, which adopted PSS as one if its main theoretical concepts, has been the dominant contributor to PSS research in recent years (Tukker, 2015). Cranfield is followed mainly by Universities from Germany and Sweden.

Table 13: Number of publications by affiliation and topic

	Affiliation	'product -service system'	Affiliation	'sustainable product -service system'
1	Cranfield University	71	Brunel University London	6
2	Universitat Bochum	55	Politecnico di Milano	6
3	Lulea Tekniska Universitet	55	Delft University of Technology	5
4	Technische Universitat Munchen	48	Universidade Federal de Santa Catarina	5
5	Linkopings Universitet	45	Aalto University	5
6	Technische Universitat Berlin	44	Universite Grenoble Alpes	5
7	Shanghai Jiaotong University	43	Loughborough University	3
8	Politecnico di Milano	38	Universita degli Studi di Bergamo	3
9	Delft University of Technology	36	University of Limerick	2
10	Universita degli Studi di Bergamo	35	Technische Universitat Berlin	2
11	Tokyo Metropolitan University	34	Open University	2
12	Sungkyunkwan University	23	National Cheng Kung University	2
13	Danmarks Tekniske Universitet	21	Blekinge Tekniska Hogskola	2
14	State Key Laboratory for Manufacturing Systems Engineering	20	Universita del Salento	2
15	Rheinisch-Westfalische Technische Hochschule Aachen	19	Universite de Lyon	2

Nevertheless, new contributions emerge from results. First, the leader country in total PSS researches is Germany. UK is well ranked in both topics, and leads SPSS studies following by Italy. Finally, results evidenced that, in spite of the fact that PSS concept was born in Europe, it later found a resonance particularly in Asian countries (i.e. China, Japan and South Korea).

Table 14: Publications by country of origin of the publishing institution

	Country	'product-service system'	Country	'sustainable product-service system'
1	Germany	295	United Kingdom	14
2	United Kingdom	193	Italy	10
3	China	152	United States	6
4	Sweden	130	Undefined	6

5	Italy	111	Brazil	5
6	Undefined	81	Finland	5
7	Japan	65	France	5
8	South Korea	60	Germany	5
9	France	59	Netherlands	5
10	Netherlands	53	Austria	2
11	United States	52	Ireland	2
12	Brazil	35	Sweden	2
13	Finland	35	Taiwan	2
14	Australia	30	Australia	1
15	Denmark	26	Belgium	1

Contrasting the publications' areas (Table 15), showed that Engineering is the leader area in both topics. In addition, regarding sustainability analyses, the ranking on SPSS highlighted the representativeness of Environmental Science and Energy areas with similar results. While in PSS studies, the position of these areas is very less representative. This suggests that SPSS investigations, embedded from a sustainable perspective, have become more important than engineering/business perspectives. On other hand, corroborating the findings by Tukker (2015), results also are suggesting that PSS research from a business perspective has become more important than environmental research.

Table 15: Publications by subject area

	Subject area	'product-service system'	Subject area	'sustainable product-service system'
1	Engineering	881	Engineering	40
2	Computer Science	394	Environmental Science	23
3	Business, Management and Accounting	322	Business, Management and Accounting	21
4	Mathematics	189	Energy	21
5	Decision Sciences	165	Decision Sciences	5
6	Environmental Science	140	Social Sciences	5
7	Energy	119	Mathematics	3
8	Social Sciences	79	Arts and Humanities	2
9	Economics, Econometrics and Finance	34	Biochemistry, Genetics and Molecular Biology	2
10	Arts and Humanities	17	Chemical Engineering	2

Based in this collection of information, the most interesting conclusions from descriptive results are probably the following. First, the substantial increasing number of studies from 2010 in PSS, advocate that the scientific interest in the PSS topic is not a temporary phenomenon fueled by a string of EU projects launched around 2000 (Tukker, 2015). Second, in spite of PSS concept was born in Europe and faces a resonance particularly in Asian, the same, until the present moment, is not true for SPSS studies (Table 11-13). A reason for this can be the recent interest by the field has occurred initially in Europe only in recent years. Third, was verified that PSS diffusion is probably even more consistently embedded in the engineering/business context than in the sustainability related literature. On the other hand, SPSS' researches are received more attention from environmental subject area (i.e. Energy, Environmental Science). Fourth, UK is well ranked in both topics, leading the research efforts in SPSS. Germany leads PSS publication.

An amplification of Tables to, for example 20 positions in the ranking, could show several non-cited but well recognized academics and enable new possible insights. All the same, considering the space limitations, we decide use fifteen as well Tukker (2015). Our results extending the theory building in PSS field contributing with insights regarding the recent interest in SPSS. Recent EU funded projects, such as Diversity, ICP4Life, Falcon, ServINNOV, REMake among others (PSS-Cluster, 2017) also reinforce the relevance of outcomes and the recent interest by field.

A number of earlier publications and special issues in top ranking journals dedicated specifically to the analysis of servitization process and broader themes related to services in product companies or PSS have been published. Table 16 provides an overview of these special issues (18) including forthcoming publications (Kowalkowski et al., 2017) and others, especially in SPSS, added by us.

Table 16: SI Publications on servitization and PSS

Theme of Special Issue	**Journal**	**Year**
Product Service Systems & Sustainable Consumption	Journal of Cleaner Production	2003
Product Service Systems: reviewing achievements and refining the research agenda	Journal of Cleaner Production	2006
The transition from product to service in business markets: An agenda for academic inquiry	Industrial Marketing Management	2008
Product-service modes of working: Operations management implications	International Journal of Operation and Production Management	2009
Setting a research agenda for service business in manufacturing industries	Journal of Service Management	2010
The Global B2B Challenge	Journal of Business & Industrial Marketing	2011
Service & solution innovation: Overview and research agenda	Industrial Marketing Management	2011

Product Service System Engineering: From Theory to Industrial Applications	Computers in Industry	2012
B2B Service Networks	Industrial Marketing Management	2013
Management of Complex Engineering Service Systems	Journal of Service Management	2014
Service Innovation in B2B Firms	Journal of Business & Industrial Marketing	2014
Servitization	Strategic Change	2014
Why have 'Sustainable Product-Service Systems' not been widely implemented? Meeting new design challenges to achieve societal sustainability	Journal of Cleaner Production	2015
Servitization of manufacturing and its implications for operations management	Production Planning and Control	2015
Design of sustainable product service systems and their value creation chains	CIRP Journal of Manufacturing Science and Technology	2016
Servitization and Deservitization	Industrial Marketing Management	2017
Service Implementation in Manufacturing Firms, Strategy, Economics and Practice	International Journal of Production Economics	In progres s
Service Transformation in Industrial Companies	International Journal of Production Research	In progres s

Approximately 60% (11) of Special Issues already realized along the servitization trajectory were published from 2012. Considering all ISs, three of them were concentred specifically on Sustainable PSS (2003, 2015, 2016) and the remaining was devoted to research community of services. The accumulation of recent ISs confirming the increasing interest on these topics. The growing interest in servitization as a research topic is also reflected in the increasing number of conferences presentations and discussions focusing on servitization, service innovation, and product-service system thinking (Kowalkowski e

Table 17: Conferences in servitization and PSS

Conference	Organization	Year initiated
International Research Symposium on Service Excellence in Management (QUIS)	Biannual symposium	1988
Frontiers in Service Conference	Annual conference sponsored by INFORMS, the American Marketing Association, and the Center for Excellence in Service at the University	1992

	of Maryland	
International Annual EurOMA Conference	Annual conference sponsored by the European Operations Management Association	1994
ServSIG International Research Conference	Biannual conference organized by the American Marketing Association's Special Interest Group for Services Marketing and Management	2001
ASAP SMF Service Management Forum	Annual Italian conference organized by the After-Sales Advanced Planning (ASAP) consortium	2003
Service Operations Management Forum	Annual workshop supported by EurOMA and EURAM	2008
Industrial Product-Service Systems Conference (IPSS)	Annual conference supported by CIRP (International Academy for Production Engineering)	2009
International Research Symposium in Service Management	Annual conference	2010
Cambridge Service Week	Annual conference organized by the Cambridge Service Alliance (founded by BAE Systems, IBM, and the University of Cambridge's Institute for Manufacturing and Judge Business School)	2010
International Conference on Business Servitization	Annual conference in Spain	2012
Spring Servitization Conference	Annual conference managed by Aston Business School's Centre for Servitization Research and Practice	2013
Service System Forum	Annual conference initiated in 2015; an initiative of the Warwick Manufacturing Group (University of Warwick)	2015
WeDPI	Annual Workshop on PSS and servitization initiated in 2015 as initiative of the University of São Paulo.	2015

4.4.2 Analyse of evolution of PSS definitions

Several terms to identify the new trend of manufacturing companies to integrate product and service exist in literature (e.g. extended products, technical services, product-service systems (PSSs). Anyway, they represent the same concept: a mix of tangible products and intangible services designed and combined to increase the value for customers. Value creation can be provided through an extended business network involving different stakeholders, which concur to create the services (Marilungo et al., 2016).

Servitization describes the growing trend for manufacturing firms to use their physical product as a vehicle for service provision (Roos, 2015). According to Roos the term was first used by Vandermerwe and Rada (1988, p.314) who de fined servitization as “the increased offering of fuller market packages or ‘bundles’ of customer focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings”. Product Service System is usually used when there is a major interest in the sustainability potentials of the offerings, while the term servitization is mostly used in a purely economic context (Annarelli et al., 2016).

The evolution of definitions of PSS over time proposed by relevant authors in this field was selected (Annarelli et al., 2016; Baines et al., 2007; Cavalieri and Pezzota; 2012; Tukker, 2015) and also from literature review and organized aiming help to understand this research stream and cover topics.

Table 18: Evolution of PSS definitions

Definition	Source
A functional economy is one that optimizes the use (or function) of goods and services and thus the management of existing wealth (goods. knowledge, and nature). The economic objective of the functional economy is to create the highest possible use value for the longest possible time while consuming as few material resources and energy as possible. This functional economy is therefore considerably more sustainable, or dematerialized, than the present economy, which is focused on production and related material flows as its principal means to create wealth.	Giarini and Stahel (1986)
“In the Service Economy, the real issue - in terms of economic value - appears to be the maximization of the combined utilization of products and services during their life time, an operation which takes into account a series of costs prior to, during, and after production.”	Giarini and Stahel (1993)
“Delivering a great product is not enough to gain a customer’s allegiance. You have to deliver a combination of services that minimizes the overall costs associated with owning and using the product.”	Wise and Baumgartner (1999)
A product service-system is a system of products, services, networks of “players” and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.	Goedkoop et al. (1999)
A PSS is: “a predesigned system of products, services, supporting infrastructure, and necessary networks that can fulfil consumers’ needs on the market; a dematerialised solution to consumer needs and preferences; a new interpretation of the product value chain and ways of delivering utility to consumers that has a smaller environmental impact than separate products and services that fulfil the same function outside the system; and a self-learning system with the goal of continuous improvement.”	Mont (1999, p. 31)
A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact then traditional business models.	Mont (2000)
A pre-designed system of products, supporting infrastructure and necessary networks that fulfill a user’s needs on the market, have a smaller environmental impact than separate product and services with the same function fulfillment and are self-learning.	Centre for Sustainable Design (2001)

A business innovation strategy offering a marketable mix of products and services jointly capable of fulfilling clients' needs and/or wants - with higher added value and a smaller environmental impact as compared to an existing system or product.	Manzini et al. (2001)
A pure product system is one in which all property rights are transferred from the product provider to the client on the point of sale [..]. A pure service system is one in which all property rights remain with the service provider, and the clients obtain no other right besides consuming the service. A product-service system is a mixture [..] of the above. It requires that property rights remain distributed between client and provider, requiring more or less interaction over the life time of the PSS.	Hockerts and Weaver (2002)
Result of an innovative strategy that shifts the centre of the business design and sale of products only (physical) to systems offering products and services that are jointly capable of satisfying a given application.	UNEP: Manzini and Vezzoli 2002
PSS is a system of products, services, networks of actors and supporting infrastructure that continuously seeks to be competitive, satisfy customer needs and have a lower impact than traditional business models.	Mont (2002)
An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands.	Manzini and Vezzolli (2003a)
A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development.	Brandsotter (2003)
PSS is a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models.	Mont (2004)
A system consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.	Tukker, 2004
PSS may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality.	Wong (2004)
PSS can be defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands.	MEPPS: van Halen et al., 2005)
PSS is defined as a system of products, services, supporting networks and infrastructure that is designed to [be]: competitive, satisfy customer needs, and have a lower environmental impact than traditional business models'.	ELIMA (2005)
Products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy.	Halme et al. (2006)
A social construction, based on "attraction forces" (such as goals, expected results and problem-solving criteria) which catalyse the participation of several partners. A PSS is a result of a value co-production process within such a partnership. Its effectiveness is based on a shared vision of possible and desirable scenarios.	Morelli (2006)
A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker and Tischner (2006b)
Product-service systems (PSS) are a specific type of value proposition that a business (network) offers to (or co-produces with) its clients. PSS 'consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs'. The PSS concept rests on two pillars: (i) Inherently taking the final functionality or satisfaction that the user wants to realise as a starting point of business development (instead of the product fulfilling this functionality). (ii) Elaborating the (business) system that provides this functionality with a 'greenfield' mindset (instead of taking existing structures, routines and the position of the own firm therein for granted).	SusProNet: Tukker and Tischner (2006a)
An advanced industrialised solution based on collaboration between social players, which	Krucken and

gives rise to both effective and efficient, highly contextualised services.	Meroni (2006)
PSS is an integrated offering of a product and a service that provides a value. Using a PSS offers the opportunity to decouple economic success from material consumption and thus reduce the environmental impact of economic activity.	Baines et al. (2007)
An attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services.	Evans et al. (2007)
'instead of assuming that all products are to be bought, owned, and disposed of by 'consumers', products containing valuable technical nutrients – cars, televisions, carpeting, computers, and refrigerators, for example – would be reconceived as services people want to enjoy. In this scenario, customers (a more apt term for the users of these products) would effectively purchase the service of such a product for a defined user period…, rather than the … [product] itself'.	McDonough and Braungart (2009)
Technical Product-Service System emphasises the physical product core enhanced and customised by a mainly non-physical service shell the investment character of all PSS components, the relatively bigger importance of the physical core of PSS and the relation between PSS manufacturers and customers.	Azarenko et al. (2009)
PSS is an integrated product and service offering that delivers value in use.	Neely (2009)
PSS is System of products and services (and infrastructure), to jointly cope with the needs and demands of customers in a more efficient way with better value for both businesses and customers, compared to only offering products [...]. PSS can decouple the creation of value from the consumption of materials and energy and thus significantly reduce the environmental impact in the life cycle of traditional product systems.	UNEP: Tischner and Vezzoli (2009)
Industrial PSS can be defined as a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life-cycle.	Jiang and Fu (2009)
IPS2 can be described as a marketable set of products and services capable of jointly fulfilling a user's need.	Rese et al. (2009)
PSS is an innovation strategy, where a greater integration of products and services has the potential to decouple business success and economic growth from mere product sales. Instead of viewing a product as an isolated entity, the PSS design activity focuses on creating the right combination of products and services, needed to aid the customer in reaching their goal.	Proteus (2010)
An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, pro- vision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system.	Meier et al., 2010
Elements of PSS are: product, service, and supporting networks and infrastructure and goals of PSS are: strives to be competitive; maximum customer value; lower environmental impact.	Wang et al (2011a,b)
PSS is defined as a solution for optimal resource operations in product life cycle through integrating tangible products with intangible services.	Zhu et al. (2011)
By supplying an integrated bundle of hardware, software, and service elements, the customer problem is solved completely. These bundles are known as product service systems (PSS) or hybrid products.	Berkovich et al. (2011)
Industrial product–service system, also known as technical-PSS, is a specific case of PSS, which focuses on provision of services for a product core that has a high net value and involves transactions in a B2B context.	Erkoyuncu et al. (2011)
The combination of existing physical products with value adding services to so called industrial product service systems (IPS2) is a promising approach for differentiation and, therefore, strengthening of the competitive position.	Schuh et al. (2011)
IPS2 are based upon product-service systems that can be defined as customer life cycle-oriented combinations of products and services to provide a higher customer value.	Meier et al. (2011)
An Integrated Product Service System (iPSS) "is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole	Zhang et al. (2012)

product life cycle".	
Integrated Service Products (ISP), in the product sales stage, to meet the clients' multi-level needs, the manufacturer provides customers with "physical product plus service" service packs; whereas, physical product is the carrier of product service, and product services are function added and the value added for the physical product. However, since the ISP combines.	Li et al. (2012)
Products and services are integrated and provided as whole set to fulfill customer's requirements and the product/service ratio can vary in different customer using contexts.	Geng and Chu (2012)
Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value.	Boehm and Thomas (2013)
PSS is an integrated offerings of tangible products, intangible services and the enabling infrastructure providing a product-unspecific functional value. While the user and the offering firm engage into an enduring contractual relationship, the ownership remains with the offering firm with the user becoming the temporary proprietor enabling a high use-flexibility.	Tietze et al. (2013)
PSS is 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 beneficial new solutions.	LeNS: Vezzoli et al. (2014)
A product-service system (PSS) is an integrated combination of products and services for optimal consumption.	Centenera and Hasan (2014)
A PSS is a system composed of a physical product and associated services that support the product through-life.	McKay and Kundu (2014)
A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers.	Tukker (2015)
A product-service system (PSS) is an industrial offer resulting from an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific and customized client demands.	Boucher et al. (2016)
PSS is a business model focused toward the provision of a marketable set of products and services, designed to be economically, socially and environmentally sustainable, with the final aim of fulfilling customer's needs.	Annarelli et al. (2016)

By analysis of this set of definitions the follow conclude points emerges: (i) first, not all definition let explicated the Triple Botton Line perspective of sustainability of PSS; (ii) comprehensive key factors to an effective PSS offer, such as: the idea of an integrated system, networks of "players", supporting infrastructure is not present in all definitions; (iii) on the other hand, the idea of fulfilling customer's needs is frequently cited in the definitions.

Fig. 7. Word cloud to PSS definitions.

A word cloud including all PSS definitions was developed in http://tagcrowd.com/ with the following criteria: the 20 most frequent words, cited at minimum 5 citations. The number in bracket is the total number of citation to each word. In this way, products appear 80 times, service, 58, PSS, 35, system 35, customer 25 and fulfilling 18 times.

4.4.3 Analysing the evolution of SPSS definitions

Looking for an actual definition is noted that, despite the SPSS have been apparently defined by first time by Maxwell and van der Vorst (2003), only recently is verified the increase of researches on SPSS business models (Table 19). Similarly to PSS, the researches in PSS are focused in large companies, neglecting SMEs (Boucher et al., 2016). In this sense, select definitions related on SPSS help the understanding this field:

Table 19: Evolution of SPSS definitions

Definition	Source
Eco-efficient services are systems of products and services which are developed to cause a minimum environmental impact with a maximum added value.	Brezet et al. (2001)
An eco-efficient service is one which reduces the environmental impact of customer activities per unit of output. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient).	James et al. (2001)
Sustainable Product and Service Development is defined here as the process of making products and/or services in a more sustainable way throughout their entire lifecycle, from conception to end of life. The products and/or services are developed to be more sustainable in a Triple Bottom Line (TBL) context (balancing economic, environmental and social aspects). This is interpreted as achieving an optimum balance between environmental protection, social equity and economic prosperity, while still meeting traditional product requirements, e.g. quality, market, technical and cost issues, etc.	Maxwell and van der Vorst (2003)
Sustainable Product and/or Service Development (SPSD) approach is a pragmatic industry support encompassing a range of strategies aimed at maximising environmental and social performance in all types of “offerings” whether they are “products”, “services” or Product	Maxwell et al. (2006)

Service Systems (PSS)	
Product-Service System Design for Sustainability is defined as: “the design of the system of products and services that are together able to fulfill a particular customer demand (deliver a ‘unit of satisfaction’) based on the design of innovative interactions of the stakeholders (directly and indirectly linked to that ‘satisfaction’ system) where the economic and competitive interest of the providers continuously seeks both environmentally and socio-ethically beneficial new solutions.	LeNS: Vezzoli et al. (2014)
A SPSS means that product-service solutions should generate satisfactory value for customers and fulfill the sustainability requirements at the same time.	Chou et al. (2015)
SPSS is “an offer model providing an integrated mix of products and services that are together able to fulfil 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”.	Vezzoli et al. (2015)
A SPSS business model is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilization and dematerialization, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage.	Barquet et al (2016a)

In contrast with previous set of PSS definition, now we find that all definitions on SPSS explicitly consider the environmental aspect or the three dimensions of sustainability. A word cloud including the SPSS definitions also was developed with the following criteria: the 20 most frequent words, cited at minimum 5 citations. Is possible note that the all words have similar frequency of citations and environmental and sustainable words have frequencies similar to product and service, proving the emphasis on sustainability.

Fig. 8. Word cloud to SPSS definitions

4.5 PSS and SPSS: two sides of same coin?

This section is devoted to discuss the main findings of selected papers highlighting the insights existent literature. Literature reviews studies provide invaluable signposts for researchers, reflecting debates and priorities at various times (Baines et al., 2017). In the sustainable service or sustainable product-service systems literature, the social aspect of sustainability tends to be neglected at the cost of environmental and economic arguments. Hence, findings extracted from well cited literature review studies and well recognized academics were examined in order to clarify the conditions under which PSS contributes to sustainability and the limits that PSS faced against the current global patterns of consumption and production. Initially, the focus of different research communities within servitization field is discussed. Next, a detailed look is given to PSS and SPSS disciplines.

4.5.1 Research communities in Service and in PSS fields

Currently there are distinct research communities providing contributions to knowledge production in the field of servitization of manufacturing, with unique and complementary perspectives, disseminated via a range of academic and scholarly journals (Lightfoot et al., 2013). Not all selected literature review papers (for example, Tukker, 2015; Beuren et al., 2013) discusses explicitly the different categories or research streams. By content analyses of studies discussing classifications emerged two principal groups of literature review studies. On the one hand, studies distinguishing the classification of the researches on Service field as a wide area, including sub-topics such as Service management, Service Science, PSS and others streams. This group focus on transformation of manufacturing goods firms to servitized firms. And, on the other hand, a second group discussing specifically the PSS topic and their sub-topics.

Table 20: Studies discussing research communities

Scope of study	Author(s)	Research Method and Databases	Time range	Studies analysed
Service field as wide area	Lightfoot et al. (2013)	Systematic literature review. Compendex, Inspec, Web of Science, Proquest, ABI Info rm and Emerald.	1961-2010	148
	Baines et al. (2017)	Systematic literature review. Compendex, Inspec, Scopus, Web of Science, ProQuest, ABI Inform, and Emerald.	1988-2015	232
	Kowalkowski et al. (2017b)	Synthesis of papers select to Special Issue and literature discussion	-	-
Specifically in PSS field	Annarelli et al. (2016)	Systematic literature review. Scopus.	1988-2016	224
	Vasantha et al. (2015)	Literature review. Main scientific databases.	2000-2014	18 literature review papers, involving around 400 studies
	Reim et al. (2013)	Systematic literature review. Scopus.	1988-2012	67
	Boehm and Thomas (2015)	Systematic literature review. EbscoHost, Springer Link, ScienceDirect, WISO	1992-2012	265

	Database, AIS Electronic Library, EmeraldInsight, Wiley InterScience, IEEEXplore, INFORMS and ProQuest.		
Velamuri et al. (2011)	EBSCO Business Source Complete, SCOPUS and WISO	1995-2010	169

Results from Baines et al. (2009a) and Lightfoot et al. (2013) indicates that the principal research communities in servitization of manufacturing field are the following: services marketing, service management, operations management, product-service systems (PSS) and service science. The scope of them is the follow:

- *Services marketing community:* have a firm foot-hold in the marketing tradition; researchers in the field of services marketing have largely evolved from a perspective of the exchange and distribution of commodities, to a focus on a customer relationship management perspective of the provision of services.
- *Service management community*: has largely evolved from mainstream operations and strategy domains and tends to focus on service organisations and organisational culture as opposed to the goods/service division.
- *Operations management community*: the broad field of operations has complemented its traditional focus on production and productivity-oriented analyses for efficiency improvements, with an emphasis on operations management and strategy in the delivery of product and service combinations.
- *Product-service systems community*: Scandinavian researchers have focussed their interest on PSS, seeking to address the ability of product-service combinations to improve social, economic, environmental and industrial sustainability. They have followed an ecological and environmental tradition.
- *Service science:* has largely evolved from information systems applied domains and generally focuses on providing a better understanding of complex service systems. Originating in the IS sector and within IBM, this is a relatively new interdisciplinary concept, articulated for the effective provision of services. Service science focuses not merely on one aspect of service, but rather on service as a system of interacting parts that include people, technology, and business. It is the study of complex service systems and the co-creation of value in complex configurations of resources.

Others studies found similar results. For example, the five principal communities contributing to servitization of manufacturing found in literature review done in Baines et al. (2017) were: 'Operations Management', 'Service Marketing', 'Innovation Management', 'Service Management' and 'Product-Service-Systems'. This research also revealed a recent increase in servitization papers published in marketing and innovation/technology disciplines. Accordingly to Kowalkowski et al. (2017b) the publications on service growth in product companies can be clustered into 'Solution Delivery', 'Solution Marketing', 'Service Business Performance', 'Services Growth Strategies', Product-Service-Systems and 'Servitization' topics. Table 21 summarized the research communities in Services mapped in literature.

Table 21: Synthesis between research communities in Services

	Author(s)			
	Baines et al. (2009a)	Lightfoot et al. (2013)	Baines et al. (2017)	Kowalkowski et al. (2017b)
Communities in Services field				
Services marketing	*	*	*	
Service management	*	*	*	
Operations Management	*	*	*	
PSS	*	*	*	*
Service science	*	*		
Innovation Management			*	
Solution Marketing				*
Solution Delivery				*
Service Business Performance				*
Services Growth Strategies				*
Servitization				*

Table 21 reveals the extent to which the research communities address the servitization since its origins. This analysis can reveal several outcomes. First, is noted that PSS and servitization are very different concepts, because PSS business models can be considered a specific topic between others which are part of wide service field. Therefore, PSS can be considered a specific type of strategy able to increase the servitization of company (Baines et al., 2017).

"The research around the servitization phenomenon appears fragmented into separate streams and suffering from an abundance of concepts – some of which appear to be incommensurable". (Brax and Visintin (2017, p. 18). Frequently publications and scholars consider 'PSS' and 'servitization' terms as synonyms, nevertheless they are not (Beuren et al., 2013). PSS is a special case in servitization, which values asset performance or utilisation rather than ownership, and achieves differentiation through the integration of product and services that provide value in use to the customer (Baines et al., 2007). According to Kowalkowski et al. (2017a) servitization can be defined as “The transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic”. While PSS is defined as “A system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models” (Mont, 2002).

The fact of a specific research community on PSS be mapped in review studies on Service field reinforce the hypothesis advocated (Baines et al., 2017) that PSS is a specific type of strategy between others available to increase the level of servitization in manufacturing. Kowalkowski et al. (2017a) distinguishes both disciplines affirming that servitization is a term commonly used to denote processes of service growth, while PSS is an engineering-led concept describing ‘innovative’ combinations of goods and services. The diversity of the definitions found in the literature suggested that scholars have yet to reach a consensus on how best to define the PSS (Beuren et al., 2013). Thus, on the whole, in spite of the growing prevalence of the PSS in academic research, the subject has yet to be comprehensively defined to enable its diffusion (Aurich et al., 2010; Beuren et al., 2013). A critical analysis suggests that, despite tremendous research interest and outputs suggesting that the research tradition is well established, the research domain of servitization is still in a theoretical and methodological nascent stage (Kowalkowski et al., 2017b).

A second interesting outcome is that Baines et al. (2017) suggest a new research community “Innovation Management”. The proposition of this community emerged from results that reveal a recent increase in servitization papers published in marketing and innovation/technology disciplines. The journal Technovation and I&M are highlights by this increase of interest “Innovation Management” in Service domain. Lastly, considering the names of categories, findings in Kowalkowski et al. (2017b) presents convergence only in the PSS category. This study not conceptualizes each category, what could favour a more precise fit. Lastly, by and large, is possible concluded that there is a reasonable level of concordance between theses authors regarding to existent research communities available.

4.5.1.1 Research communities in PSS

Particularly, a heated controversy concerns the sustainable impact of PSS such as innovative systems. The PSS concept was initially considered to be a promising initiative to influence on sustainable production and consumption patterns. However, it is now stated by scholars that PSS do not necessarily lead to sustainable solutions (Boucher et al., 2016).

A relevant stream of the literature, mainly rooted in the European research, has assigned an increasing emphasis to the role of PSS as a concrete response to emerging pressures. The basic idea behind this role of PSS concept is that it pushes innovation strategy, shifting the business focus from the design and sales of physical products to the design and sales of a system consisting of products, services, supporting networks and infrastructures, which are jointly capable of fulfilling specific market demands (Marilungo et al., 2016). The systematic review in Annarelli et al. (2016) identified the following PSS main current research streams to the domain based considering the quantity of publications available: focus on strategy, on design, on sustainability, on ICT, production and lastly in logistic/network. They concluded that sustainability is losing its main role among research fields, though it does remain important.

Annarelli et al. (2016) also distinguished the PSS literature studies in four research communities. The 'Economists' providing only an economic assessment of PSS potential. 'Environmentalists' dealing exclusively with the environmental/social analysis. 'All-Around' providing both analyses. And the 'Designers' writing about neither the economic nor the environmental/social analysis. They also identified a set of the main aspects of PSS, which are ‘Market proposition/Customer needs’, ‘Concept of system’, ‘Effect on environment’, ‘Networks and infrastructures’, ‘Tangibility and intangibility’ and ‘Social aspects and partnership’. They corroborated previous findings (Tukker, 2015; Boucher et al., 2016) confirming that, even though PSS started its development linked to sustainability and environmental aspects, nowadays these topics are no longer the most influent aspects of PSS research efforts.

Similar findings in Vasantha et al. (2015) corroborate the de-couple of sustainability issues in PSS literature. “More papers relate to engineering, computer science and business, management and accounting, suggesting that PSS research from a business perspective has become more important than environmental research” (Tukker (2015, p. 78). Aiming define a ontology of current PSS researches, Vasantha et al. (2015) identified the most frequent meaningful terms/phrases in 18 PSS review papers covering more than 400 studies published. The most cited categories identified of works in PSS were the following: business, life-cycle, customer requirement, product and service, value chain, environmental impact and network and infrastructure. These results showed that only one category, the ‘environmental impact’, is devoted specifically to sustainability issues. Within this category the most frequent terms cited are: sustainable consumption, sustainable product, sustainable development, eco-efficient service, production and consumption, material intensity, life-cycle oriented and environmentally conscientious.

Scholars also tend to discuss PSS business models and implications for implementation using five distinct sets of tactics. Tactics are defined as the company's residual choices at an operational level after deciding which business model to apply (Evans et al., 2007; Reim et al., 2015). Five prominent tactics related to contracts, marketing, network, product and service design and sustainability were identified in the systematic review by Reim et al. (2015). These tactics emerged as the content analysis of the articles was conducted, specifically through open coding technique. The term ‘tactics’ has also been used explicitly in PSS studies to describe decisions that improve the amount of value created after choosing a particular business model (Evans et al., 2007; Reim et al., 2015).

By analyses in 265 studies, Boehm and Thomas (2103) found the following perspectives views on PSS research: Strategic view (competitive advantage, concepts & barriers), Organizational view (organizational design, networks, organizational capabilities, system integration), Marketing view (pricing, customer satisfaction), Design view (strategic perspective, design process, design attributes), Innovation view (innovation management, transition), Business level view (business models, viability in specific industries, engineering & information technology), Sustainability view (human behavior & consumption, evaluation of sustainability), Macroeconomic perspective (prevalence & effect, policy making), and Meta-level view. Even as in Baines et al. (2017) results, Boehm and Thomas (2103) found a category related to Innovation topic.

Table 22: Research communities in PSS

	Authors

	Annarelli et al. (2016)	Vasantha et al. (2015)	Reim et al. (2015).	Boehm and Thomas (2013)	Velamuri et al. (2011)
Research streams					
Product and service		*	*		
Economists	*			*	*
Environmentalists	*	*	*	*	*
All-Around	*				
Design	*			*	*
Business		*		*	*
Life-cycle		*			
Customer requirement		*			
Value chain		*		*	
Network and infrastructure		*	*		
Marketing			*	*	*
Contracts			*		
Strategic view				*	*
Innovation				*	*
Meta-level				*	
Organizational					*

The specific research stream in PSS topics suggests concordance between the presence of ‘Environmentalists’ and relative concordance in ‘Product and service’ and in ‘Network and infrastructure’ research communities. In short, it is possible concluded that, although developed in unconnected research streams and coming from different points of departure, there is a striking overlap in concepts relating to servitization within the operations management and PSS communities (Lightfoot et al., 2013). The following findings also emerged from research streams:

- Emergent communities of PSS and service science are drawing on a knowledge base more evenly distributed across all the researcher communities (Lightfoot et al., 2013).
- The field of PSS research is not fully mature and there is a need to identify the most urgent research directions for design methodologies. It is at an initial stage of development and substantial research is required to develop a practical PSS design methodology (Vasantha et al., 2012).
- There are significant variations in engagement and interaction amongst the communities and also a shared interest in the conceptualizing product service differentiation, competitive strategy, customer value, customer relationships and product-service configuration (Lightfoot et al, 2013).

Probably the most relevant finding from analyse of studies is that exist several opportunities for increasing interactions and integration between the existent communities resulting in leveraging the production of stock of knowledge. The current evident distancing between them ends up becoming a critical constraint affecting the practical diffusion of more successful servitization cases around the world. Boehm and Thomas (2013, p. 255) corroborate stating: “A recommendation from us is here to avoid citation syndicates: In many articles we found that some authors always cite in their articles the same set of contributions.” As a result, the increasing of interactions will take to improvements on cohesion and integration between communities for thought leadership on servitization (Lightfoot et al, 2013). Finally, to enhance the industrial applicability of the proposed methodologies, collaboration between researchers and practitioners has to be emphasized.

4.5.2 The Limits of PSS

This section discusses the several limitations faced in PSS domain strengthening the perspective of SPSS models. Nowadays, PSS is a subject that discussed in a variety of research fields. PSS is investigated by researchers interested mainly in sustainable design, also by researchers involved in engineering design, business management and information systems. This has made the field more complex, since these communities each tend to have their own focus and vocabulary, but at the same time it ensures that the topic of PSS is now researched from different perspectives and that there is less chance of ‘blind spots’ occurring (Tukker, 2015).

The analysis of 10,028 firms in 25 countries revealed that although sales revenue was larger for sertvitized manufacturing firms, they also generated lower profits as % of sales (Vasantha et al., 2015). The status quo is similar for environmental impacts. Thus, it is not guaranteed that sertvitized companies would have less environmental impacts than “normal” companies. Unless PSS solutions are specially designed to be eco-friendly, there is no guarantee that they will reduce environmental impacts. Thus, as conclusion, the design phase plays a crucial role in developing a sustainable PSS including business profits, environmental friendly and social merits (Vasantha et al., 2015).

Furthermore, the society as a whole is a set of complex, inter-related systems that are not clearly understood. As a result, unforeseen circumstances may turn potential environmentally sound solutions into increases in global consumption of environmental resources at the practical level. One example is the impact of PSS on consumer behaviour where leasing, rather than ownership of products, could lead to careless (less ecological) behaviours (Vezzoli et al., 2015). Certain customers, accustomed to possessing goods, may refuse to accept the consumption of products without owning them. Certain providers, wanting to be competitive and to supply innovative products, will have misgivings about what to charge for this type of business; they will focus primarily on the risks they must take and the changes they must make. Consequently, to create novel and successful business models, these barriers must be overcome (Beuren et al., 2013).

Kowalkowski et al. (2015) highlights the need to break free from the product–service continuum discourse. They complement previous studies with two main findings. The first assumption emphasizes the importance of balancing expansion and standardization activities, thus raising questions about how to prioritize resources and product- and service-related activities. While the second assumption emphasizes the importance of managing the co-existence of different roles and provides a more complex view of service-led growth activities, as well as of how to manage customer relationships.

Findings from literature also have demonstrated that PSS business models may indeed have a negative effect on the environmental issues, resulting only in economic benefits (Barquet et al., 2016a; Halme et al., 2004; Tukker, 2015; Doualle et al., 2015). The most applications fail to consider the social balance and, to a certain extent, the environmental impacts. This observation cannot be squared with the definitions of the PSS, which underscore sustainable development (Beuren et al., 2013). For example, schemes where products are borrowed and returned incur transportation costs (and the resultant use of fuel as well as pollution emissions) over the life of the product. In some specific instances, the total fuel cost and environmental impact may make the system non-viable in the long term (Vezzoli et al., 2015).

Regarding to existence of artefacts supporting the service infusion, it is notable the absence of models to support and generate sustainable PSS (Vasantha et al., 2012). This is one of several reasons why implementing successful eco-efficient PSS is still very limited. A range of tools and methodologies exist for the conception of the PSS. However, an assessment of how these tools perform in practice is still required. Companies normally use tools and methodologies for traditional design but frequently fail to consider the whole system (Beuren et al., 2013). As a result, according to Vasantha et al. (2015) the main challenges to the effective sustainability assessment of PSS are the following:

- Many research studies use sub-optimized solutions without covering the whole life cycle stages and involvement of multiple stakeholders. The assessment should be considered as multi-criteria decision-making (MCDM) problems to avoid sub-optimization.
- PSS solutions are assessed to understand environmental issues. However, support is required to make design alternatives that are environmentally friendly.
- Developing a sustainable solution is an iterative process. Methodologies are needed to develop systems that are flexible enough to adapt to changes without requiring major updates.
- Most of the demonstrated sustainability assessments have limitations in terms of defining system boundaries. There are exclusions of important features that could have changed the assessment results. A system needs to be established to test validity of the sustainability results.
- Sustainability analysis, comparing the different stands/views taken by various stakeholders, is needed.
- A better support system is needed for defining and managing multiple variable types, especially uncertain variables.
- Is needed to define a complete PSS life-cycle model.
- The quality relies on the availability of data. Availability of data is a greater challenge in PSS sustainability assessment.

As such, the PSS business model might be the critical factor that distinguishes PSS with positive results in terms of eco-efficiency and sustainability from those that do not capture environmental potential (Reim et al., 2015; Ceschin, 2013). Ideally, PSS design should focus on integrating business models, products and services together throughout the lifecycle stages, creating innovative value addition for the system in the three dimensions of sustainability (Vasantha et al., 2012).

Despite potential benefits and numerous examples of successful servitization in many sectors, most companies have found it far from straightforward to achieve the expected revenues, profits and customer satisfaction (Kowalkowski et al., 2017a). On this context, the company's size denotes the availability of resources, competences, and level of strategic flexibility, which can influence both the composition of and use of the tactics or residual choices. Comparatively a start-up and a large company, for example, vary significantly regarding how they would implement certain PSS business models (Reim et al., 2015).

Finally, future study of PSS evaluation should care more about sustainability. Regarding to environmental (dis)advantages of PSS, Tukker (2015) stated that PSS is not the sustainability panacea. Renting, leasing and sharing can have environmental benefits since, in principle, the same service level can be achieved with the use of fewer artifacts. However, leased products tend to be used less carefully than products that are owned, and rented, leased or shared products may be returned earlier to the service provider in comparison to the lifetime of a product sold in the traditional manner. Although PSS is advocated because of its advantages in environmental protection, rather limited researches focused on sustainability. Moreover, the success of a PSS not only relies on a good design, but also on its operation and management (Qu et al., 2016).

4.5.3 The necessary transition towards SPSS

Based on previous related constraints of PSS business models in cover a TBL vision, several aspects corroborated the need of a more systemic thinking oriented to sustainability dimensions to obtain a successful service infusion. While the literature diverges on the importance of sustainability in PSS, several academics believe that sustainability is one important property of PSS (Wang et al., 2011). They believe that PSS is a way of dealing with unsustainable patterns of consumption, contributing reducing consumption through alternative scenarios of product use, with closing material cycles, increasing overall resource productivity and dematerialisation improving resource and functional efficiency of each element (Mont, 2004; Wang et al., 2011). PSS might still take to the dematerialisation and creation of sustainable products through decreasing the creation of waste and the consumption of raw materials (Cook, et al., 2006; Wang et al. 2011; Maussang et al., 2007; Halme et al. 2004).

From an environment viewpoint, PSSs can be more efficient thanks to a more conscious product usage, increased resource productivity and a close loop-chain manufacturing (Marilungo et al., 2016). PSS also have the potential to do so and could help to move in the direction of sustainability. However, this potential requires being implemented and verified depending on every contextualized case of new business model implementation (Boucher et al., 2016).

The highest potential for sustainability improvements in PSS offer results from either increased/improve resource utilization and the extent of innovations, which may make the production or delivery process more sustainable (Reim et al., 2015). Use-oriented PSS potentially intensify the use of material products and hence could reduce the need for materials, but a possible drawback is that they could prompt less careful use, leading to quicker wear and tear. Result-oriented PSS have the greatest potential and provide an incentive to reduce material costs but require the most radical change in the business model compared with product sales, which hampers their broad implementation and hence real contributions to resource-efficiency and circularity (Tukker, 2015).

However, despite of related expected benefits, the more general challenge remaining for the deployment of PSS is the ability to manage the overall transformation of business models, and notably to ensure their convergence towards a higher sustainability (Boucher et al., 2016). This occur because PSS that are not developed carefully run the risk that the environmental potential will be offset by rebound effects and less careful behaviour (Reim et al., 2015; Tukker, 2015).

The challenges for the development of PSS, suggested by Vasantha et al. (2012) indeed reinforce the limits of traditional PSS perspective and the need of more effective SPSS business models embedded in a TBL perspective. These challenges are the following:

- integrate economic, environmental and social considerations in a holistic approach in order to produce radical changes and identify the degrees of freedom for change in the overall production and consumption system;
- environmentally conscious design and manufacturing in closed-loop economies must strongly consider customers' behaviour in the use phase;
- PSS must afford opportunities for manufacturers to develop the business potential of environmentally conscious design and differentiate their products by meeting diversely segmented customer needs in a sustainable manner;
- methodological tools for designers must be developed to analyse PSS as social constructs and extend value and functional units to include the prolificacy of social

and cultural significances of products and services such as history, status, prestige, identity and so forth.

- must provide more convenience through service so as to intensify physical use with less energy and material consumption;
- must consider product design within the product life-cycle perspective and combine the design phases and activities with corresponding organizational issues to provide product engineers with efficient means for optimization in the life cycle perspective;
- the cost of the PSS (including monetary cost as well as physical load, mental load, and environmental burdens) must be compared to the value provided;
- sustainability, availability and higher customer satisfaction must be guaranteed over the life cycle due to intensified service and knowledge content and data sharing throughout the product life cycles;
- to identify the main stakeholders in the business relationships and develop close collaboration between the customer and supplier in an iterative procedure involving needs, expectations and solution-exploration that ultimately would lead to the creation of the functional product.

Besides it is important to underline that not all shifts to PSS result in environmental benefits. PSS may need to be specifically designed, developed and delivered, if it is to be highly eco-efficient. Even when well designed, it has been observed that some PSS changes could generate unwanted side effects, usually referred to as rebound effects (Vezzoli et al., 2014, 2015; Tukker, 2015). Studies reviewed suggest that companies should actively strive to optimize their use of resources and design their PSS offers to be more sustainable and avoid rebound effects (Tukker, 2004, 2015; Tukker and Tischner, 2006b).

Corroborating these statements, findings in Vasantha et al. (2012) shows that the focus on SPSS is only mentioned but with no support to achieve it. Hence, significant support need be created to help the generation of SPSSs schemes. In this same line, results evidenced that the major issue for future contributions in the PSS field is to look across borders and integrate results from other disciplines and research communities (Lightfoot et al, 2013). To enhance the industrial applicability of the proposed methodologies, collaboration between researchers and practitioners has to be emphasized through spurring up challenges in two dimensions: ontology and models for the representation of PSS, as argue Vasantha et al. (2012).

Although PSS represents a potential path toward sustainable resource use, it requires radical transformations for product-oriented and service-oriented companies at the value-chain and industrial level (Martinez et al., 2010; Reim et al., 2015). The business models of the PSS frequently emphasize its economic aspects, and therefore, in future studies, researchers should delve into the environmental and social aspects of this topic. These aspects may, in fact, act as the main barriers to achieving a wholly successful PSS (Beuren et al., 2013).

The background of literature confirms that, although PSS domain emerged from the sustainability field, its development is not still matured. There is, therefore, an opportunity to develop stage gate evaluation processes for the whole PSS life cycle. The PSS evaluation domain need specific focus on feedback loops between stages (Vasantha et al., 2015).

During the process of transformation towards PSS, industries still will require support in terms of tools, techniques and methods. Thus, they need assistance to develop systems ready to deliver offerings over prolonged periods of time (Vasantha et al., 2012). Moreover, the developments of tools for modeling the PSS proposal as well as assessing the extent of the environmental benefit are necessary (Beuren et al., 2013; Vezzoli et al., 2012). Results from literature shows that the necessity to incorporate multi-disciplinary approaches within the design methodologies is only mentioned. Thus, since PSS design is inter-disciplinary, many multi-disciplinary approaches should to be incorporated in the design process to create viable and sustainable PSS offers (Vasantha et al., 2012).

In short, is verified that the interest in PSS for environmental reasons has received a new boost from the recent revival of interest in resource-efficiency among important actors in civil society, business and government (Tukker, 2015). Nevertheless, the PSS efficiency still needs to be defined and accepted across the PSS research community (Vasantha et al., 2015) for further achieve an effective diffusion on companies. In short, considering all above limitations of PSS in attend the sustainability demands of an economy based in mutual integration of products-services, a more dedicated socio-technical (Mylan, 2015; Ceschin, 2013; 2014) discipline is necessary. This discipline must be able to overcoming the traditional business perspective of value creation, to an effective TBL-oriented perspective within and across the enterprises. To comprehend this domain, Vezzoli et al. (2015) promotes the term SPSS instead of simply PSS. They highlighting which SPSS offer is effectively a win e win proposition: environmentally, socio-ethically and economically sustainable at the same time. In summary, the literature states that the transition to SPSS is a promise discipline in this direction.

4.5.4 Challenges for explore the full potential of SPSS

McAloone and Pigosso (2017) stated that together with the shift from products to PSS as a standard sustainability design object, the basic approach has shifted, so as to incorporate more sustainable decision points at a given time, thereby encompassing a systems approach towards sustainability enhancement. Nevertheless, many companies are not yet realizing the full benefits of their efforts towards sustainability improvement, often rendering sustainability as an activity that may not any longer be seen as a net cost to the company, but is still not a sufficient value-creator in itself.

Barquet et al. (2016a, p. 436) defined Sustainable Product-Service System (SPSS) as “an approach to achieve benefits in the three dimensions of sustainability”. Therefore, this research streams discussed on literature, differently from traditional PSS statements and definitions, advocate that the SPSSs are intrinsically embedded in a Triple Bottom Line (economic, social and environmental) perspective of sustainability. According to Vezzoli et al. (2015) the SPSS definition could provide not only a higher customer satisfaction, but also a great advantage on the three dimensions of sustainability. From an economic viewpoint, SPSSs can create new market potentials, higher profit margins and can contribute to higher productivity by means of reducing investment costs along the lifetime as well as reducing operating costs for the final users (Marilungo et al., 2016).

One of the reasons why eco-efficient service concepts have not been as successful in the market as their proponents would hope is especially related with those directed to consumers acceptance (Halme et al., 2004; Ceschin, 2013). The diffusion of an SPSS in the consumer market is highly dependent on being sensitive to the culture in which it will be used. Thus it is important to take into account that the success of offer depends on the culture of the population. Consumers in certain parts of the world are more likely to accept the PSS than those from other parts. Consideration of the cultural conditions is necessary for the PSS implementation, and a company should first verify that the correct conditions appear to be in place (Beuren et al., 2013). Aligned with these propositions, Wong (2004) recognized that SPSSs have been more readily accepted in communal societies like Scandinavia and in some countries from Europe such as the Netherlands and Switzerland, than in many other countries (Wong, 2004; Vezzoli et al., 2015). These regions are related examples of well-developed regions recognized by favourable social and cultural aspects.

The limited diffusion of SPSS, in particular, such as car sharing systems, shared use of do-it-yourself tools and washing services, can be explained simply by the factors such as high transaction costs, the weakness of the company position in the value chain, mainly where excellence in product manufacturing and design form the key to uniqueness and hence power in the value network among other reasons (Tukker, 2015). In same line, Vezzoli et al. (2015) affirm that significant barriers to SPSS diffusion are related with user acceptance and adoption of these novel systems. This may be due to existing habits, how the service provider is perceived, financial reasons or other empirically documented factors that make users feel unsure (Vezzoli et al., 2015). Besides, considering these aspects, other reason to the limited diffusion of SPSS is that it will never be easy for a provider to overcome the perception that he is putting his consumer in a relatively dependent position or influencing, or even prescribing, how his consumer should behave (Tukker, 2015).

For these reasons and also pulled by a main interest in the strategic value of PSS, the literature is focusing more and more on factors related to business perspective of PSS, because of the growing importance of raising customer acceptance of service-oriented offers (Annarelli et al., 2016). As consequence of this focus on customers, the debate on sustainability perspective (social, environmental and economic) has wakened in PSS communities and increasing in SPSS scholars.

Hence, keeping the social sustainability perspective explicitly in mind when assessing the added value of eco-efficient services to consumers would perhaps allow a better scrutiny of issues that are relevant to their decision-making (Halme et al., 2004). Since first studies on PSS, the topics ‘Environmental/Social dimension’ and ‘PSS design and implementation’ have been recognized as future research (Annarelli et al., 2016). Nonetheless, despite this expectative in last decades, until the moment the available stock of knowledge and practical evidences in theses topics demonstrate that the TBL perspective of PSS still is not widely comprehended and accepted by the different research communities on service field (see Baines et al., 2017; Annarelli et al., 2016; Lightfoot et al., 2013; Vasantha et al., 2015). Therefore, the absence of an effective TBL perspective, and mainly of aspects evolving the social dimension within the research communities, may be one of main reasons that explain the low diffusion of SPSS in enterprises of across-sectors.

In this direction, another relevant challenge to SPSS diffusion refers to integration between the existents academics communities (section 5.1 and 5.2). Given, the servitization of manufacturing is associated with the market delivery of combined manufactured products with services, the more established communities need to better recognise the diversity emerging communities within the entire service research landscape and ensure future specialisation in their communities is pursued in a more informed manner (Lightfoot et al., 2013).

The service research community also seems to lack a common lexicon and analytical tools that might structure scholarly or practice-led debate (Kowalkowski et al., 2017). Another problem with the topic of servitization is that scholars use disparate terms to describe transformation toward advanced services and the boundaries of those terms remain blurred (Baines et al., 2017; Hou and Neely, 2013). Eloranta and Turunen (2015) also found a lack of clarity regarding strategic management theories in servitization. Thus, the uniformisation and integration of a common lexicon, ontology (see Gaiardelli et al., 2014 and Vasantha et al., 2015), lessons learned or even analytical tools is very necessary. This will contribute to more oriented debates and an oriented stock of knowledge, turning possible solving the questions that still remain unanswered presents on literature. This also enables companies to better understand this field. In a nutshell, establishing where the service growth strategy works and under what conditions, is a fundamental first step to justify its effectiveness and will be instrumental in building the credibility for research to influence practice (Kowalkowski et al., 2017b).

Other important challenge to service communities remains regarding to systematic methods and tools engaging the SPSS life cycle. Nowadays, environmental analyses mainly employ qualitative and descriptive methodologies. Nevertheless, there is a need for new quantitative methodologies, capable of describing and evaluating also indirect effects on social and environmental dimension attributable to PSS (Annarelli et al., 2016). In this sense, the increased relevance of the life cycle perspective in modern society calls for more sustainable approaches to design, engineer and construct everyday products and related services. In order to respond to such a requirement, designers and engineers need to have access to new methods and tools that are able to integrate the life cycle perspective of PSS in a proper way (Cavalieri et al., 2012).

Following the methodology proposed in 1999 by Goedkoop et al. there is a clear need for new innovative analysis covering all the three dimensions of PSS sustainability potential (Annarelli et al., 2016). Thus, more systematic quantitative methods and tools able to integrate the life cycle of SPSS based in a TBL perspective are necessary. In short, an embedded TBL approach is essential to evaluating the overall payoff of a PSS offer and underscores the importance of all three components working together (Lee et al., 2012; Reim et al., 2015). Therefore, an important challenge is not only to conceive SPSS concepts, but also to understand the contextual conditions in which they are introduced and to explore the suitable strategies and development pathways to embed these concepts in society (Vezzoli et al., 2015).

The rule of competences also represents a challenge towards a SPSS fluid transition. Since the capabilities and knowledge for producing and selling products are considerably different from those of managing SPSS offers, it is clear that companies require new competences, skills and experiences, in relation to both management and design activities (Vezzoli et al., 2015; Xing and Ness, 2016). In Small-sized-Medium-Enterprises, this limitation can be more sensitive yet (Clegg et al., 2017; Pardo et al., 2013). This means that there is the need to structure the organisation in a way to be competent in designing, making and delivering SPSS offers, acquire SPSS design methods/tools to develop and assess them, acquire life-cycle costing methods and develop performance metrics to measure the organisation's ability in effective and efficient delivery of SPSS offers (Vezzoli et al., 2015).

In the same way, since service growth in product firms necessitates a certain organizational ambidexterity in terms of managing the co-existence of (and synergies between) product-centric and service-centric capabilities, further research should investigate the interrelationship between this ambidexterity, service business models and the competitive advantage of the firm (Kowalkowski et al., 2017b). In sum, although many questions remain unanswered or need to be answered more convincingly, a picture of how manufacturing organisations should be configured to deliver advanced services is emerging. However, researchers have given less attention to processes of servitization (Baines et al., 2017).

In addition, it is possible concluded that since one relevant barrier to the implementation and diffusion of SPSSs is the lack of knowledge within firms and in consultancy companies. Hence, governments should act on the dissemination of information and know-how about the benefits of SPSSs. Furthermore, the dissemination of successful SPSS case studies and systematic methods/tools to design and implement such innovations are necessary strategies (Vezzoli et al., 2015). In summary, there are several challenges to the development and delivering of SPSSs, requiring the building of strong collaboration among the actors evolving in this complex system.

4.5.5 Guiding Research Communities Towards a Successful SPSS Transition: a Circular Economy perspective

Several outcomes from literature reinforce the need of redefine the current patterns of consumption and production in order to not compromise the boundaries of resources available in the planet. The increasing recognition of the need to mitigate the effects of population growth, wealth increase and human consumption is currently leading several international organizations to consensually highlight the need for a significant changes in our economic system, aiming to respect boundaries resources of nature (McAloone and Pigosso, 2017). With up to three billion people likely to join the global middle class by 2050 competition for resources will inevitably grow. As a result, improving the productivity of resources such as water and land by around a factor of two and energy by a far higher factor would make a substantial contribution to reducing resource depletion and the threat of climate change (Tukker, 2015).

In 1972 the book "*Limits to Growth*" (Meadows et al. 2006) published the first computerised simulation of the effects of the ongoing system of production and consumption on nature. It was the first scientific forecast of a possible global eco-system collapse. These effects can occur in two directions: (i) inputs, namely extracting substances from the environment, and; (ii) outputs, emitting substances into the environment (Vezzolli et al., 2014). Regarding output (emitting resources) according to these authors, the main environmental impacts and the main environmental effects of such impacts can be listed:

Table 23: The main environmental impacts and their environmental effects

Environmental impact	Environmental effects
Global warming (greenhouse effect)	Melting of polar ice-caps, rising seawater levels, inundated lowlands, desertification, migration of pathogens.
Ozone layer depletion	Damage to flora and fauna, elevated skin tumour risk, immune system weakening.
Eutrophication	Loss of aquatic fauna due to oxygen depletion, contamination of groundwater and lakes, resulting in non-drinkable water obstacles to swimming.
Acidification	Limited regrowth of forests, limited regrowth of trees in urban zones, corrosion of monuments and buildings, contamination of groundwater, loss of aquatic fauna, sanitary risks (respiratory problems).
Smog	Some organic compounds (e.g. aldehydes) provoke lacrimation and irritate respiration, some compounds (e.g. PaN) can have toxic effects on plants.
Toxic emissions	Dioxin (TCDD) provokes chloracne and soft tissue cancer, inhaling pyrene and benzopyrene is highly carcinogenic, lead poisoning (saturnism) may cause irreversible neurological damage
Waste	The presence of waste: reduces availability of waste disposal sites pollutes soil and groundwater, creates olfactory pollution and explosion hazard in landfills. Waste transportation implies in fuel consumption, noise and air pollution.
Others	Olfactory pollution, acoustic pollution, electromagnetic pollution, deterioration of the landscape.

Following this context and risks to future of society, according to Annarelli et al. (2016) an important current and future research stream in PSS field is incorporate the researches about business models and collaborative consumption in PSS domain. Tukker (2015) highlighted that the resource-efficiency as one of the flagships of Europe 2020 strategy. According to McAloone and Pigosso (2017) some examples of on-going initiatives lead by international organizations are: the roadmap for developing energy efficient and low-carbon societies by 2050, developed by the European Union; the ‘green growth’ framework to foster economic growth while ensuring the availability of natural resources, by the Organisation for Economic Cooperation and Development (OECD); and the Sustainable Development Goals (SDGs), launched by the United Nations in 2016.

The transition to sustainable development clearly passes through a disorderly fashion that involves changes in the current production models, with and without the help of academic research; improvements in the efficiency of energy use, transportation, and waste management; coupled with a gradual change in consumer behavior and involvement. The next steps in this transition also include an increase in the use of renewable energies to replace ultimately the use of fossil fuels which are the main source of present environ mental problems (Almeida et al., 2017).

As argued Vezzolli et al. (2015), there is an urgent need not only to address production processes, products and provision of services, but to also redesign the patterns of consumption ("lifestyles"), as well as the institutions that underpin them e and to learn how all of them can be addressed simultaneously, to make the transformation to sustainable societal processes. Unfortunately, considering all research advances and at the current stage of development of PSS domain, there is still a need to clarify and assess the impact of PSS in all three dimensions (economic, environmental, and social) of the so-called Triple Bottom Line (Lee et al., 2012; Anarelli et al., 2016).

In this direction, the SPSS business models are expected to produce synergies in profit, competitiveness and environmental benefits and to renew stakeholder's partnerships in a new convergence of economic interests and concomitant systemic resources optimization (Boucher et al., 2016) in an eco-efficiency perspective (Vezzoli et al., 2015). Thus, the transformation towards SPSS introduces a new relationship between product and user in PSS, where we see that the user no longer is the legal owner of the product (Demyttenaere et al., 2016).

In order to successfully achieve these benefits, SPSSs carry great potential to deliver social well-being and economic prosperity while operating within the limits of our planet (Vezzolli et al., 2015). For this reason, intrinsic SPSS business models, embedded in a TBL perspective represents the more suited alternative available. PSS allows firms to de-couple economic growth from environmental pressure while satisfying consumers' needs, constituting an important strategic market opportunity (Annarelli et al., 2016). Whereas SPSS business models are focused on eco-efficiency (Vezzoli et al., 2015) and are intrinsically TBL-oriented.

Analysing Tukker (2004) and Tukker and Tischner (2006) seminal papers, Vasantha et al. (2015) affirm that those studies discussed ways to achieve factor 4 sustainability, the three main types of PSS as well as that PSS problem has two important interacting variables: economic and environmental. However, most of the PSS literature separate economic and environmental variables considering them individually (Vasantha et al., 2015). Hence, results shows that there is a really low number of studies providing an comprehensive analysis capable of covering all the three dimensions of sustainability (Annarelli et al., 2016). Even so, successful commercial SPSS examples are still more likely to be B2B than B2C offerings (Vezzoli et al., 2015).

The motives and advantages for deploying sustainability tactics in PSS models can be driven by three broad factors. First, legal and market conditions can be important motivators for companies to endeavour to use the full potential of the PSS offering in terms of sustainability. Second, customers may favour PSS offers with a higher sustainability focus, because they are likely to represent greater value to the customers' business operations. Third, PSS providers can be inclined to emphasize sustainability because it promotes exploring novel technologies, developing solutions, and implementing business models that meet both economic and environmental goals (Reim et al., 2015).

The SPSS concept seems, therefore, to be a valuable and promising concept to tackle sustainability issues, but it does not represent a silver bullet. Thus, it is crucial to explore the potential synergies among SPSS and other promising and interwoven sustainability concepts (Vezzoli et al., 2015). This exploration can also enable a better understanding of indicators and performance measures and provide impetus for further evolvement of tools and methods for SPSS design. Recent investigation by McAloone and Pigosso (2017) found that companies and universities are increasing the focus on how to create better processes towards sustainable product development, rather than simply creating yet another tool or a method. With this elevation of activities to the level of PSS, systems thinking and closed loop operations, companies are increasingly engaging the middle-management (tactical) levels of their business and product development activities, in order to understand how to leverage greater parts of the companies' value-adding activities, through more tactical deployment of sustainability thinking.

Sum up these potential advantages of SPSS, when comparing with the traditional PSS business models, another positive perspective to respond to the society demands is the advance of Circular Economy (CE) in governmental and academic debate. CE is considered as a solution for harmonizing ambitions for economic growth and environmental protection aligned with eco-industrial development. It can be understood as the realization of closed loop material flow in the whole economic system. Besides, in association with the so called 3R principles (reduction, reuse and recycling) “the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases” (Lieder and Rashid, 2016).

A formal definition to CE is “an industrial economy that is restorative or regenerative by intention and design” (Ellen Macarthur Foundation, 2013). “A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models” (World Economic Forum, 2014, p. 15).

Such an economy it is also based on a few strategic principles (Fig. 9). According to the first principle, the CE aims to design out waste. Thus, waste does not exist and products are designed and optimized for a cycle of disassembly and reuse. Second, consumables in the CE are largely made of biological ingredients or ‘nutrients’ that are at least non-toxic and possibly even beneficial, and can safely be returned to the biosphere, either directly or in a cascade of consecutive uses. Third, the energy required to fuel this cycle should be renewable by nature, again to decrease resource dependence and increase systems resilience, for example, to oil shocks (World Economic Forum, 2014).

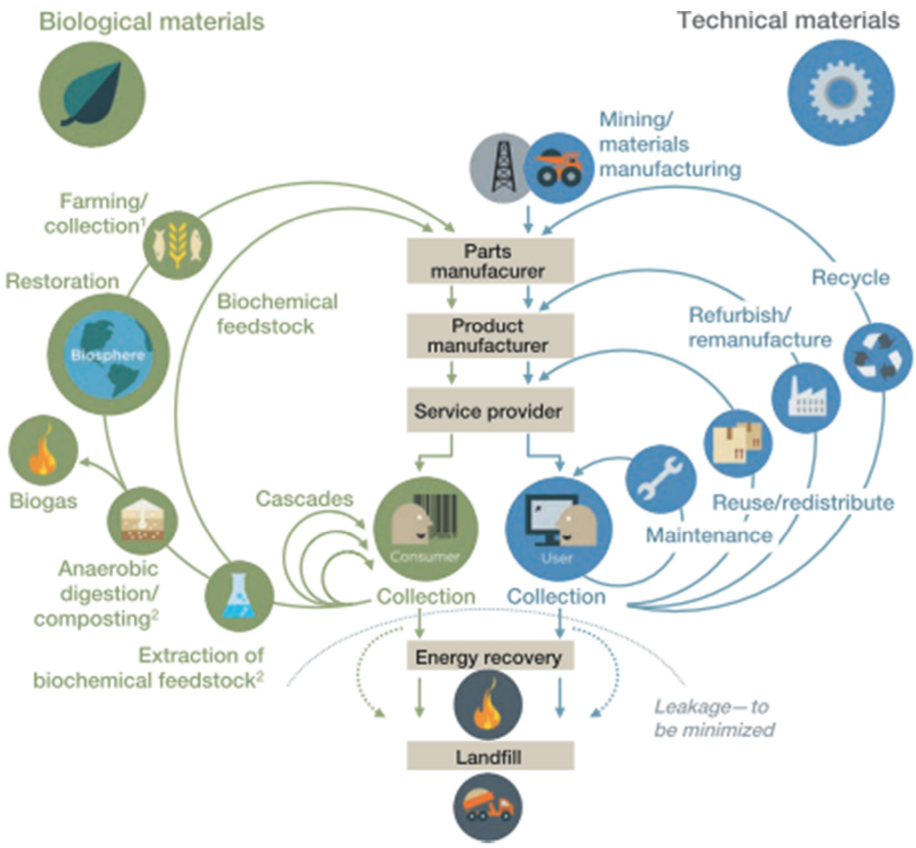

Fig. 9. The circular economy: an industrial system that is restorative by design. Source: World Economic Forum (2014).

Recently, a transition towards CE and the integration of social innovation into sustainability initiatives can be observed, carrying to strategic and holistic sustainability considerations in the design of complex systems (McAloone and Pigosso, 2017). Furthermore, the exploration of the CE potential offers a new way to think innovatively about products in servitization field. Spring and Araujo (2017) found that the relationship between servitization and sustainability suggested by the CE goes far beyond what is implied from a producer-centric approach with its narrow focus on incentives for dematerialisation, and repair and maintenance as restorative functions. From a CE advantage point, the entrepreneurial opportunities for services connected to products are much larger than those implied by the servitization and encompass reverse as well as forward supply chains. In a nutshell, the closed and reverse loops of the enable several opportunities for entrepreneurial service creation and new SPSS business models (Fig. 9).

Based on the principles of CE, and in the closed loop material flows (Fig. 9), there are four main sources of value creation in the CE. They can be understood as a window of opportunity to explore in order to favour the SPSS offers.

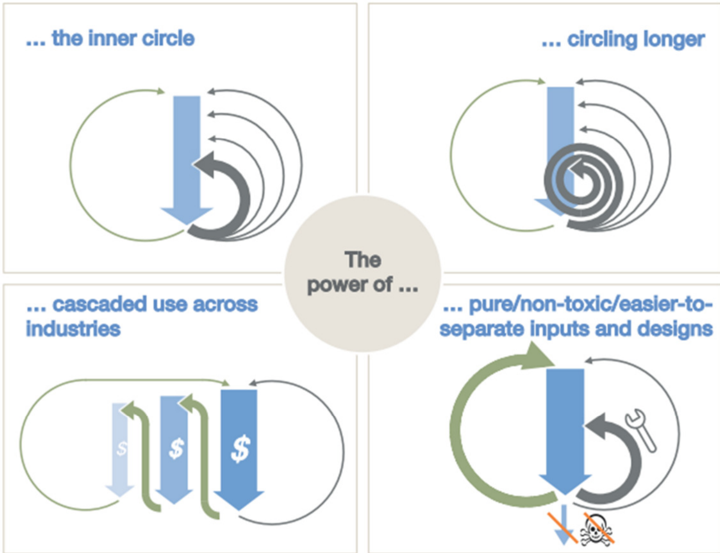

Fig. 10. Sources of value creation in the CE. Source: World Economic Forum (2014).

These service sustainable-oriented opportunities can be explains in the follow manner (World Economic Forum, 2014):

- The power of *the inner circle* refers to minimizing comparative materials use vis-à-vis the linear production system. The tighter the circle, i.e. the less a product has to be changed in reuse, refurbishment and remanufacturing and the faster it returns to use, the higher the potential savings on the shares of material, labour, energy and capital still embedded in the product, and the associated externalities (such as greenhouse gas (GHG) emissions, water and toxicity).
- The power of *circling longer* refers to maximizing the number of consecutive cycles (be it repair, reuse, or full remanufacturing) and/or the time in each cycle. Each prolonged cycle avoids the material, energy and labour of creating a new product or component.
- The power of *cascaded use* refers to diversifying reuse across the value chain, as when cotton clothing is reused first as second-hand apparel, then crosses to the furniture industry as fibre-fill in upholstery, and the fibre-fill is later reused in stone wool insulation for construction - substituting for an inflow of virgin materials into the economy in each case - before the cotton fibres are safely returned to the biosphere.
- The power of *pure inputs*, lies in the fact that uncontaminated material streams increase collection and redistribution efficiency while maintaining quality, particularly of technical materials, which in turn extends product longevity and thus increases material productivity.

Spring and Araujo (2017) corroborate saying that the economically-inspired notion of servitization and the ecologically-inspired CE share common precursors. As such, they have comprised similar shifts in relationships and practices, but with different primary aims. However, now that sustainability is becoming a much more mainstream corporate concern, the aims as well as the practices are converging rapidly. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, to achieve a better balance and harmony between economy, environment and society (Ghisellini et al., 2016).

In line with these outcomes and based on an analysis of current trends and past developments in product and PSS domains, McAloone and Pigosso (2017) develop a comprehensive scenario of how current initiatives might possibly deploy over the next decade in the perspectives for a more sustainable and CE (Fig. 10).

	Past	Present	Future
Mains goals	Product	PSS	Eco-efficiency, sharing and collaboration
Expected results	End-of-pipe => Proactive	Proactive => Sustainable	Sustainable => Restauratory
Main aim	Tool building	Tool implementation	Consolidate integration
Basic Approach	Singular problem approach	System approach	Holistic approach
Envisaged Cost x Benefit	Sustainabity = Cost	Sustainabity = no extra value	Sustainabity = Business
Sustainabity view	Environment	Environment + Social	Environment + Social capital + Economic
Business mindset	Linear economy	SPSS + closing loops	SPSS enabling full Circular Economy
What are we changing	Improve product	Improve process and services	Improve competences and awareness
Decision-making level involved	Operational	Tactical + Operational	Strategic + Tactical + Operational
Mains research challenges	More sustainable products	Difusion of concepts and consumer acceptance	Integrate research communities and consumer acceptance

Fig. 11. Evolutional path. Source: the authors, based on McAloone and Pigosso (2017).

In this direction, the rising of a sharing economy and collaborative consumption is seen as a window of opportunity that can be exploited to favour the acceptance of SPSS-oriented solutions (Vezzoli et al., 2015) in a CE context. In this concern, supportive policies and the stimulation supported by designs that enhance rather than limit customer experience and, from the firm's perspective will contribute to the diffusion of SPSS in a CE.

The diffusion also will be unlocked with the understanding into how the risks from a transition from a product-centered firm to a SPSS-centered firm can best be managed. This seems pivotal for realizing a true CE and/or a resource revolution via the implementation of SPSS (Tukker, 2015). Challenges to community interested in both SPSS and CE disciplines also evolve strategies to achieve a wide a diffusion of these concepts between academics and in society, as a whole, and the consumer acceptance. As consequence, a bottom line in this direction passes by integration of research communities and the establishment of a common typology to servitization field. Finally, top-down sustainability efforts as well as bottom-up efforts on firms, supply chain networks, and government regulations are enablers expected.

The Internet of Things co-evolving with the CE closed-loops (Fig. 9) as well as the four sources of value creation (Fig. 11) also are relevant enablers of new forms of sustainable service business models arising, from continuous tracking of the biographies of products and the interaction of multiple biographies in complex systems (Spring and Araujo, 2017). To concluded, from all these mentioned reasons, SPSS has emerged as a class of hybrid business models that have evolved particular relevance to enterprises operating in a more resource-efficient and CE perspective (Vasantha et al., 2015).

4.6 Discussion and Conclusions

Our main proposal was to understand the current discussion addressed by different research communities in service field, investigating if PSS and SPSS can be considered independents disciplines. We have exposed the foundations on which the limitations of PSS reinforce the controversy on its real sustainable impact to both companies and society. A systematic literature review was performed following a structured research protocol. Systematic review are useful to supporting others researchers to define and validated research questions. This type of research also is especially in order to guiding further research efforts in a certain domain. Initially, a comprehensive list of keywords was used as input to performe the search process on Scopus and WoS databases of studies related with this topic.

The descriptive analyses based in several indicators extracted from literature, contributed with generation of knowledge regarding the evolution and focus of publications in PSS and SPSS, the journals where the research communities share their publications, the representative scholars and regions of research groups in both topics. As result, a very recent increase interest by ‘sustainable product-service system’ topic is past recent years was noted. As a result of these recent increase number of investigations and due the time for diffusion of results, the literature available and, as consequence, the stock of knowledge is still very limited. On the whole, our analysis of the relevant literature revealed a movement towards sustainability and Circular Economy debate.

In sum, our findings are based on a sequence of methodological research procedures to investigate the conditions under which PSS and SPSS contribute or not to a TBL perspective of sustainability. Results from previous literature and also several factors consolidating in this study confirm the hypotheses that PSS and SPSS might be considerate distinct, although no totally independent disciplines. Several are the factors that support this hypothesis. First, the comprehensive content analyses of evolution of most cited definitions in PSS and SPSS available, since their origins, suggest a distinct vision between them. On one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. On the other hand, SPSS concept is based on eco-efficiency and in a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy.

A second factor corroborating this hypothesis is related with the past and current need to redefine the current patterns of consumption/production in order to not compromise the boundaries of resources available in the planet. In order to achieve this goal, SPSS offer a more systemic thinking to the society demands. The third relevant factor is the increasing recognition of the need to mitigate the effects of population growth, wealth increase and human consumption. Fourth, several previous findings from systematic literature review have stated that PSS literature clearly separate economic and environmental variables considering them individually (Vasantha et al., 2015).

This last aspect occur because SPSS are eco-efficiency (Vezzoli et al., 2015) and intrinsically TBL-oriented (Barquet et al., 2016). As consequence, for this reason SPSS carry great potential to deliver social well-being and economic prosperity while operating within the limits of natural resources available (Vezzolli et al., 2015). Fifth, our findings reveal several distinct research communities and research streams available in the wide service field. The comprehension of their specific research focus, sum up with the results of literature showing an interesting stock of knowledge on sustainable services, corroborated the hypothesis advocated in which SPSS as a particular discipline is becoming a mainstream research interest. Finally, the combinations of these related factors reinforce the internal validity of results.

Three billion people likely to join the global middle class by 2050 resulting in increasing competition for resources (Tukker, 2015). This is a fact. In order to not compromise the boundaries of natural resources available in the planet, recent initiatives developed by the EU, OECD and UN are devoted to develop a more sustainable energy efficient and low-carbon societies in next decades. These actions are on-going facts. Therefore, based in these statements, undoubtedly there is the need of development of more effective and sustainable-rooted and TBL-rooted business models to enlarge the diffusion of service-oriented economy.

Therefore, considering that since first investigations on PSS in 1990', the topics related to Environmental and Social dimensions have been recognized as future research trend in PSS field (Annarelli et al., 2016) and that until the moment show low effective practical diffusion in different contexts and countries, the stock of knowledge in SPSS field need be increase. As a consequence, from these hard challenges and aiming to avoid a dangerous stagnation of research communities to these above questions, emerge the need of an effective integration and cohesion between the different research streams available in literature. Thus, a start point in this direction for all research communities in the wide service field is "avoid citation syndicates" (Boehm and Thomas, 2013, p. 255). News insights helping the diffusion of servitization field will emerge from this integration between communities (see Spring and Araujo, 2017).

Due to the recognition of the systemic sustainability challenge faced by our society, a change towards extended collaboration within and across value chains is expected. This change must be focused on developing new solutions and economic systems, bringing together different stakeholders in society, that help addressing the planetary boundaries (McAloone and Pigosso, 2017; Annarelli et al., 2016; Tukker, 2015). For these reasons, SPSS models, embedded in a TBL perspective may be seem as one of the most suited strategies in order to creating a more sustainable society oriented to resource scarcity and to products disposal into a CE perspective. Finally, findings from literature evidence that there is a clear consensus on that the business models based on CE only may be effectively realized with the development of products/services and with SPSS that can be easily disassembled, remanufactured, recycled and reused (McAloone and Pigosso, 2017; Tukker, 2015).

Although the results of our research may contribute to advance in theory-building on sustainability in PSS and mainly in SPSS transition, limitations should be considered. Initially, the literature review studies selected cover different scholars and research academics communities. This turns more complex the consolidation of findings. In this sense, different methodological procedures could be applied to support this process generating new insights. In relation to systematic review, others eligibility criteria could eventually be adopted for publications selection. For example, studies written in a language different than English have been excluded. This research also used only formal literature available in scientific databases, does not including books or grey literature. The decision to limit the systematic review to engineering, design management, and business related journals. The contributions coming from others different areas could be inserted.

Further empirical research is needed to investigate how the tension between more sustainable and eco-innovators products and eco-services can be best managed. Problems and risks related to resource scarcity and products disposal will be minimized by an enhanced uptake of the concept of CE embedded in a SPSS dominant logic. Thus, comprehend the rule of internalization of competences and change mind-sets to support this transition are research paths need. In order to avoid contextual biases, we suggest that scholars also need focus on the proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and End-Of-Life) in order to minimize the effects of lack of competence of companies and support the managers to conduce the transformation.

Additionally, contextual variables are often missing in literature. In particular, further researches should give a special look in Small-sized-Medium-Enterprises. They are a key actor to the global economy. At least 80% of all global enterprises are considered SMEs (Moore and Manring, 2009) and according to European Commission (2011) SMEs represent with over 99% of European enterprises and around two-thirds of European employments. Lastly, the perspectives on SPSS in low-income and emerging economies and ways to leverage social innovation for sustainability are relevant key directions.

In sum, this study offers important contributions to practice as well. On the whole, our findings extend and complement the well-cited previous studies based on literature review (Tukker, 2015; Lightfoot et al., 2013; Baines et al., 2009a; Annarelli et al., 2016) addressing relevant gaps pointed by literature. A set of advantages and disadvantages issues of the PSS and SPSS are also covered by our study. The understanding of research background provided a common basis to investigate efficiently these topics. Furthermore, the iterative exploratory content analysis of recent selects studies and from well recognized scholars, yields new constructs and correlation based in insights of literature analyses. These results can orient academics, companies and governmental entities to establish actions and research efforts in these important domains.

Appendix I - Analysed papers on PSS and SPSS

Author(s)	Title	Year	Journal	Research purpose	Research Methodolog y
Baines et al.	Servitization: revisiting the state-of-the-art and research priorities	2017	International Journal of Operations & Production Management	Theory refinement	Literature review
Kowalkowski et al.	Servitization and Deservitization: Overview, Concepts, and Definitions	2017a	Industrial Marketing Management	Descriptive	Literature review
Kowalkowski et al.	Service growth in product firms: Past, present, and future	2017b	Industrial Marketing Management	Descriptive	Literature review
Spring and Araujo	Product biographies in servitization and the circular economy	2017	Industrial Marketing Management	Theory building	Literature review
Qu et al.	State-of-the-art of design, evaluation, and operation methodologies in product service systems	2016	Computers in Industry	Descriptive	Literature review
Marilungo et al.	Review of Product-Service System Design Methods	2016	IFIP	Descriptive	Literature review
Annarelli et al.	Product service system: A conceptual framework from a systematic Review	2016	Journal of Cleaner Production	Theory building	Literature review
Barquet et al.	Sustainability factors for PSS business models	2016a	Procedia CIRP	Descriptive	Case study
Ghisellin et al.	A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems	2016	Journal of Cleaner Production	Descriptive	Literature review
Xing and Ness	Transition to product-service systems: principles and business model	2016	Procedia CIRP	Theory building	Case study
Demyttenaer e et al.	The influence of ownership on the sustainable use of product-service systems - A literature review	2016	Procedia CIRP	Descriptive	Literature review
Lieder et al.	Towards circular economy implementation: a comprehensive review in context of manufacturing industry	2016	Journal of Cleaner Production	Theory building	Literature review
Kjaer et al.	Challenges when evaluating Product/Service-Systems through Life Cycle Assessment	2016	Journal of Cleaner Production	Exploration	Literature review
Boucher et	Editorial: Design of sustainable product service systems and their	2016	CIRP Journal of Manufacturing	Descriptive	Literature

al	value creation chains		Science and Technology		review
Tukker	Product services for a resource-efficient and circular economy - A review	2015	Journal of Cleaner Production	Descriptive	Literature review
Reim et al.	Product e Service Systems (PSS) business models and tactics e a systematic literature review	2015	Journal of Cleaner Production	Theory refinement	Literature review
Vezzoli et al.	New design challenges to widely implement ‘Sustainable Product e Service Systems’	2015	Journal of Cleaner Production	Theory building	Literature review
Kowalkowski et al.	What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies	2015	Industrial Marketing Management	Theory building	Literature review
Vasantha et al.	Advances in Designing Product-Service Systems	2015	Journal of the Indian Institute of Science	Theory refinement	Literature review
Mylan	Understanding the diffusion of Sustainable Product-Service Systems: Insights from the sociology of consumption and practice theory	2015	Journal of Cleaner Production	Theory refinement	Conceptual study
Eloranta and Turunen	Seeking competitive advantage with service infusion: a systematic literature review	2015	Journal of Service Management	Descriptive	Literature review
Centenera and Hasan	Sustainable product-service system	2014	International Business Research	Descriptive	Case study
Beuren et al.	Product–service systems: a literature review on integrated products and services	2013	Journal of Cleaner Production	Descriptive	Literature review
Boehm and Thomas	Looking beyond the rim of one’s teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems	2013	Journal of Cleaner Production	Descriptive	Literature review
Lightfoot et al.	The servitization of manufacturing: A systematic literature review of interdependent trends	2013	International Journal of Operations & Production Management	Descriptive	Literature review
Ceschin	Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies’	2013	Journal of Cleaner Production	Theory building	Case study
Hou and Neely	Barriers of Servitization: Results of a Systematic Literature	2013	Spring Servitization Conference	Descriptive	Literature review
Cavaieri and Pezzotta	Product–Service Systems Engineering: State of the art and research challenges	2012	Computers in Industry	Theory refinement	Literature review
Vasantha et al.	A review of product-service systems design methodologies	2012	Journal of Engineering Design	Descriptive	Literature review
Lee et al.	Dynamic and multidimensional measurement of product e service system (PSS) sustainability: a triple bottom line (TBL)-based system dynamics approach	2012	Journal of Cleaner Production	Theory building	Conceptual study

Velamuri et al.	. Hybrid value creation: a systematic review of an evolving research area	2011	Journal fur Betriebswirtschaft (Management Review Quarterly)	Descriptive	Literature review
Wang et al.	Status review and research strategies on product-service systems	2011	International Journal of Production Research	Theory building	Conceptual study
Meier, Roy, Seliger	Industrial product-service system - IPS2	2010	CIRP Annals - Manufacturing Technology	Theory building	Conceptual study
Baines et al.	Towards an operations strategy for product-centric servitization	2009	International Journal of Operations & Production Management	Theory building	Literature review
Baines et al.	State–of–the–art in product service systems	2007	Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture	Descriptive	Literature review
Halme et al.	Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability	2004	Ecological Economics	Theory building	Conceptual study
Manzini and Vezzoli	A strategic design approach to develop sustainable product service systems: examples taken from the ‘environmentally friendly innovation’ Italian prize	2003	Journal of Cleaner Production	Theory building	Case study
Wise and Baumgartner	Go downstream-The new profit imperative in manufacturing	1999	Harvard Business Review	Theory building	Conceptual study

REFERENCES

Almeida, C.M.V.B., Agostinho, F., Huisingh, D., Giannetti, B.F. 2017. Cleaner Production towards a sustainable transition. Journal of Cleaner Production 142, 1-7.

Annarelli, A., Battistella, C., Nonino, F. 2016. Product service system: A conceptual framework from a systematic Review. Journal of Cleaner Production 139, 1011-1032.

Aurich, J.C., Mannweiler, C., Schweitzer, E., 2010. How to design and offer services successfully. CIRP Journal of Manufacturing Science and Technology 2 (3), 136-143.

Azarenko, A., Roy, R., Shehab, E., Tiwari, A., 2009. Technical product-service systems: some implications for the machine tool industry. J. Manuf. Technol. Manag. 20 (5), 700-722.

Baines, T., Bigdeli, A. Z., Bustinza, O.F., Shi, V.G., Baldwin, J., Ridgway, K. 2017. Servitization: Revisiting the State-of-the-art and Research Priorities. International Journal of Operations & Production Management, in press.

Baines, TS, Lightfoot H, Steve E, Neely A, Greenough R, Peppard J, Roy R, Shehab E, Braganza A, Tiwari A, Alcock J, Angus J, Bastlm M, Cousens A, Irving P, Johnson M, Kingston J, Lockett H, Martinez V, Michele P, Tranfield D, Walton I, Wilson H. 2007. State–of–the–art in product service systems. In: Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221(10): 1543-1552.

Baines, T., Lightfoot, H., Peppard, J. 2009a. Towards an operations strategy for product-centric servitization, Journal of Operations & Production Management, Vol. 29 No.5, pp.494-519.

Barquet, A. P., Seidel, J., Seliger, G., Kohl, H. 2016a. Sustainability factors for PSS business models. Procedia CIRP 47: 436 – 441.

Barquet, A. P., Seidel, J., Buchert, T., Galeitzke, M., Neugebauer, S., Oertwig, N., Rozenfeld, H., Seliger, G. 2016b. Sustainable product service systems – from concept creation to the detailing of a business model for a bicycle sharing system in Berlin. Procedia CIRP 40: 524 – 529.

Berkovich, M. et al., 2011. Requirements Engineering for Product Service Systems - A State of the Art Analysis, Business and Information Systems Engineering (BISE), 6 (3), Springer.

Beuren, F.H., Ferreira, M.G.G., Miguel. P.A.C. 2013. Product–service systems: a literature review on integrated products and services. Journal of Cleaner Production 47: 222-231.

Bitzer, B., Biernatzki, R., 2004. Product service engineering limitations & future needs for SMES. Shaker, Aachen.

Boehm, M., Thomas, O. 2013. Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. Journal of Cleaner Production 51, 245-260.

Boucher, X., Brissaud, D., Shimomura, Y. 2016. Editorial: Design of sustainable product service systems and their value creation chains. CIRP Journal of Manufacturing Science and Technology 15: 1–2.

Brandstotter, M., Haberl, M., Knoth, R., Kopacek, B., Kopacek, P. 2003. IT on demand – towards an environmental conscious service system for Vienna (AT). In: Third International Symposium on Environmentally Conscious Design and Inverse Manufacturing – EcoDesign'03, 799–802.

Brax, S.A., Visintin, F. (2017). Meta-model of servitization: The integrative profiling approach. Industrial Marketing Management 60: 17–32.

Brezet, J.C., Bijma, A.S., Ehrenfeld, J., Silvester, S., 2001. The Design of Eco-efficient Services. TU Delft for the Dutch Ministry of Environment, Delft, Netherlands.

Cavalieri, S., Pezzotta, G. 2012. Product–Service Systems Engineering: State of the art and research challenges, Computers in Industry, 63 (4): 278–288.

Cavalieri, S., Pezzotta, G., Shimomura, Y., 2012. Editorial: Product–service system engineering: From theory to industrial applications. Computers in Industry 63: 275–277.

Centenera, J., Hasan, M. 2014. Sustainable product-service system. Int. Bus. Res. 7 (7):62-71.

Ceschin F. 2014. Sustainable product-service systems: Between strategic design and transition studies. Springer Science & Business Media. 122p.

Ceschin, F. 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production 45: 74-88.

Clegg, B., Little, P., Govette, S., Logue, J. 2017. Transformation of a small-to-medium-sized enterprise to a multi-organisation product-service solution provider. International Journal of Production Economics. In press.

Cook, D.J., Greengold, N.L., Ellrodt, A.G., Weingarten, S.R., 1997. The relation between systematic reviews and practice guideline. Ann. Intern. Med. 127 (3), 201-216.

Cook, M.B., Bhamra, T.A., and Lemon, M., 2006. The transfer and application of product service systems: from academia to UK manufacturing firms. Journal of Cleaner Production, 14 (17), 1455–1465.

Demyttenaere, K., Dewit, I., Jacoby, A. 2016. The influence of ownership on the sustainable use of product-service systems - A literature review. Procedia CIRP 47: 180 – 185.

Doualle, B., Medini, K., Boucher, X., Brissaud, D., Laforest, V. 2016. Design of sustainable product-service systems (PSS): towards an incremental stepwise assessment method. Procedia CIRP 48:152–157.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research: A Method for Science and Technology Advancement. Springer. pp.161.

ELIMA Report. Environmental life cycle information management and acquisition for consumer products, 2005.

Eloranta, V., Turunen, T. 2015. Seeking competitive advantage with service infusion: a systematic literature review, Journal of Service Management, 26 (3): 394 – 425.

EPA (2009). "Green Servicizing" for a More Sustainable US Economy:Key concepts, tools and analyses to inform policy engagement. US Environmental Protection Agency Office of Resource Conservation and Recovery, Washington, D.C.

Erkoyuncu, J. A., Roy, R., Shehab, E. Cheruvu, K. Understanding service uncertainties in industrial product-service system cost estimation, International Journal of Advanced Manufacturing Technology, 52, 2011.

European Comission (2016). User guide to the SME Definition. Available in: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/

European Commission. 2011. Minimizing Regulatory Burden for SMEs. Adapting EU Regulation to the Needs of Micro-Enterprises. Final report. European Commission: Brussels, Belgium, 2011.

Evans, S., Partidario, P.J., Lamberts, J., 2007. Industrialization as a key element of sustainable product-service solutions. Int. J. Prod. Res. 45 (18 e 19), 4225-4246.

Falcon (2016). http://www.falcon-h2020.eu/

from http://www.product-life.org/milestone2.htm

Gaiardelli, P., Resta, B., Martinez, V., Pinto, R., & Albores, P. (2014). A Classification Model for Product-Service Offerings. Journal of Cleaner Production, 66, 507-519

Geng, X., Chu, X., 2012. A new importance e performance analysis approach for customer satisfaction evaluation supporting PSS design. Expert Sys. Appl. 39, 1492-1502.

Giarini, O., Stahel, W. (1986). The Functional Economy: Cultural and Organizational Change. Hidden innovation' in: Science & Public Policy, London, vol 13 no 4, August 1986. Available in:http://www.product-life.org/en/archive/the-functional-economy-cultural-and-organizational-change

Giarini, O., Stahel, W. R. (1989/1993). The limits to Certainty, facing risks in the new service Economy. Kluwer Academic Publishers, Dorddrecht, Boston, London.

Giarini, Orio and Stahel, Walter R. (1989/1993). The Limits to Certainty - Facing Risks in the New Service Economy. Boston. Mass.: Kluwer Academic.

Ghisellini, P., Cialani, C., Ulgiati, S. 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production 114: 11-32.

Goedkoop, M., van Halen, C., te Riele, H., Rommens, P. 1999.Product service-systems, ecological and economic basics", Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ), . Gough D, Oliver S, Thomas, J. 2012. An Introduction to Systematic Reviews, London:Sage. Publications, 304 p.

Halme, M., Anttonen, M., Hrauda, G., Kortman, J., 2006. Sustainability evaluation of European household services. J. Clean. Prod. 14, 1529-1540.

Halme, M., Jasch, C., and Scharp, M., 2004. Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability. Ecological Economics, 51 (1–2), 125–138.

Hockerts, K., Weaver, N. 2002. Are Service Systems Worth Our Interest? Assessing the Eco-efficiency of Sustainable Service Systems. Working Document INSEAD, Fontainebleau, France.

Hou, J. and Neely, A. 2013. Barriers of Servitization: Results of a Systematic Literature. Proceedings of 2013 Spring Servitization Conference, Aston University, UK.

James, P., Slob, A., Nijhuis, L., 2001. Environmental and Social Well Being in the New Economy. In: Sustainable Services e an Innovation Workbook. University of Bradford, TNO. NL/GB.

Jiang, P., Fu, Y., 2009. A new conceptual architecture to enable iPSS as a key for service-oriented manufacturing executive systems. Int. J. Internet Manuf. Serv. 2 (1), 30-42.

Kjaer, L.M., Pagoropoulos, A., Schmidt, J. H., McAloone, T.C.2016. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. Journal of Cleaner Production 120, 95-104.

Kowalkowski, C., Gebauer, H., Kamp, B. & Parry, B. 2017a. Servitization and Deservitization: Overview, Concepts, and Definitions. Industrial Marketing Management, 60, 4-10.

Kowalkowski, C., Windahl, C., Kindström, D. Gebauer, H.2015. What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies, Industrial Marketing Management 45:59–69.

Kowalkowski, C., Gebauer, H., Oliva, R. 2017b. Service growth in product firms: Past, present, and future. Industrial Marketing Management,60, 82-88.

Krucken, L., Meroni, A., 2006. Building stakeholder networks to develop and deliver product-service systems: practical experiences on elaborating pro-active materials for communication. J. Clean. Prod. 14, 1502-1508.

Lee, S., Geum, Y., Lee, H., Park, Y., 2012. Dynamic and multidimensional measurement of product e service system (PSS) sustainability: a triple bottom line (TBL)-based system dynamics approach. J. Clean. Prod. 32, 173-182.

Li, H., Ji, Y., Gu, X., Tang, R. 2012. Module partition process model and method of integrated service product. Computers in Industry 63(4): 298–308.

Lieder, M., Rashid, A. 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. Journal of Cleaner Production 115:36-51.

Lightfoot, H., Baines, T., Smart, P. 2013. The servitization of manufacturing: A systematic literature review of interdependent trends, International Journal of Operations & Production Management, 33 (11/12):1408 – 1434.

Manzini, E., Evans, S., Collina, L. 2004. Solution oriented partnership. How to design industrialised sustainable solutions. Cranfield University, Cranfield.

Manzini, E., Vezzoli, C. 2002. Product-service-systems and Sustainability, Opportunities for Sustainable Solutions. Politecnico di Milano, UNEP, Paris.

Manzini, E., Vezzoli, C., 2003a. A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize. J. Clean. Prod. 11 (8), 851-857.

Manzini, E., Vezzoli, C., 2003b. Product-service Systems and Sustainability: Opportunities for Solutions. UNEP, Division of Technology Industry and Economics, Production and Consumption Branch.

Manzini, E., Vezzoli, C., Clark, G., 2001. Product service systems: using an existing concept as a new approach to sustainability. Journal of Design Research 1, 12–18.

Marilungo, E., Peruzzini, M., Germani, M. 2016. Review of Product-Service System Design Methods. In: A. Bouras et al. (Eds.): PLM 2015, IFIP AICT 467, 271–279, 2016.

Martinez, V., Bastl, M., Kingston, J., Evans, S., 2010. Challenges in transforming manufacturing organisations into product e service providers. J. Manuf. Technol. Manag. 21 (4), 449- 469.

Maussang, N., Brissaud, D., and Zwolinski, P. 2007. Common representation of products and services: a necessity for engineering designers to develop product-service systems. In: Proceedings of the 17th CIRP Design Conference, Berlin: Springer-Verlag, 463–471.

Maxwell, D., van der Vorst, R. 2003. Developing sustainable products and services. Journal of Cleaner Production 11: 883–895.

Maxwell, D., Sheate, W.; van der Vorst, R. 2006. Functional and systems aspects of the sustainable product and service development approach for industry. Journal of Cleaner Production, 14 (17): 1466-1479.

McAloone, T. C., Pigosso, D.C.A. 2017. From Ecodesign to Sustainable Product/Service-Systems: A Journey Through Research Contributions over Recent Decades: 99 – 111. In: R. Stark et al. (eds.), Sustainable Manufacturing, Sustainable

Production, Life Cycle Engineering and Management, DOI 10.1007/978-3-319-48514-0_7

McDonough, W., & Braungart, M. (2009). Cradle to cradle: Remaking the way we make things. London: Vintage.

McKay, A., Kundu, S., 2014. A representation scheme for digital product service system definitions. Adv. Eng. Inform. 28, 479-498.

Meadows, D., D. Meadows and J. Randers (2006) Limits to Growth: The 30-year update (Chelsea Green, White River Junction, VT).

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

Meier, H., Roy, R., Seliger, G., 2010a. Industrial product-service system - IPS2. CIRP Ann. e Manuf. Technol. 59, 607-627.

Meier, H., Uhlmann, E., Krug, C.M., Volker, O., Geisert, C., Stelzer, C., 2010b. Dynamic IPS2 networks and operations based on software agents. CIRP J. Manuf. Sci. Technol. 3, 165-173.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. 2009. The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097.

Mongeon P, Paul-Hus A. 2016. The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics 106 (1):213-228.

Mont, O. (1999), Product-Service Systems, AFR-Report 288, Natur Vards Verket, Lund. Schmidt-Bleek, F. (1994), Wieviel Umwelt braucht der Mensch? MIPS – Das Maß für ökologisches Wirtschaften. Basel/Boston/Berlin: Birkhäuser Verlag.

Mont, O. (2000). Product-Service Systems, AFR-Final Report 288, Swedish Environmental Protection Agency: Stockholm, Sweden.

Mont, O. 2001. Introducing and developing a Product-Service System (PSS) concept in Sweden. The International Institute for Industrial Environmental Economics (IIIEE).

Mont, O., 2002. Clarifying the concept of product-service system. J. Clean. Prod. 10, 237- 245.

Mont, O., 2004. Institutionalisation of sustainable consumption patterns based on shared use. Ecological Economics, 50 (1–2), 135–153.

Mont, O., 2004a. Product-service Systems: Panacea or myth? Ph.D. Thesis. Lund University, Sweden.

Morelli, N., 2006. Developing new product service systems (PSS): methodologies and operational tools. J. Clean. Prod. 14, 1495-1501.

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

Mylan, J. 2015. Understanding the diffusion of Sustainable Product-Service Systems: Insights from the sociology of consumption and practice theory. Journal of Cleaner Production 97:13-20.

Neely, A., 2009. Exploring the financial consequences of the servitization of manufacturing. Oper. Manag. Res. 1, 103-118.

Ness, D. 2009. Sustainable Product Service Systems: Potential to Deliver Business and Social Benefits with Less Resource Use. In H. Wang (Ed.), Web-Based Green Products Life Cycle Management Systems: Reverse Supply Chain Utilization (pp. 232-249). Hershey, PA: IGI Global. doi:10.4018/978-1-60566-114-8.ch010

Neves-Silva, R., Pina, P., Spindler, P., Giuditta, G., Mourtzis, D., Lazoi, M., Campos, A. R. 2016. Supporting context sensitive lean product service engineering. Procedia CIRP 47:138 –143.

Niemöller, C., Özcan, D., Metzger, D., Thomas, O. 2014. Towards a Design Science-Driven Product-Service System Engineering Methodology. DESRIST: 180–193.

Oliva, R., Kallenberg, R. (2003). Managing the transition from products to services. International Journal of Service Industry Management 14 (2): 160–172.

Omann, I. 2003. Product-service systems and their impacts on sustainable development – a multi-criteria evaluation for Austrian companies. Frontiers, 1-34.

Orloff, D., Heinz, S. M. 2015. Sustainable product service systems in small and medium enterprises - from a case study on textile leasing to a Design Thinking Workshop for Sustainable Product Service System Development for Sustainable Product-Service System Development. Master Thesis in Sustainability Science. Universitat Luneburg. 160 p.

Klein, P., Lützenberger, J., Thoben, K.D. 2016. Exploiting the increasing amount of Product Usage Information to support the development of Through-life Engineering Services. TESConf 2016 – The 5th International Conference on Through-life Engineering Services, 1st – 2nd November 2016, Cranfield, United Kingdom

Pardo, H.R.J., Bhamra, T., Bhamra, R., 2013. Exploring SME perceptions of sustainable product service systems. Engineering Management, IEEE Transactions 60: 483–495.

Pigosso, D.C.A., McAloone, T.C. 2016. Maturity-based approach for the development of environmentally sustainable product/service-systems. CIRP Journal of Manufacturing Science and Technology 15: 33–41.

Pigosso, D.C.A., Sousa, S.R., Guelere Filho, A., Ometto, A.R., Rozenfeld, H. 2010. Is the Industrial Product-Service System really sustainable? In: CIRP IPS2 Conference, 59-65.

Proteus (2010). Available in: http://orbit.dtu.dk/en/projects/innovation-consortium-proteus--productservicesystem-tools-for-ensuring-useroriented-service(e4a05c23-b61e-443d-89eb-560a56a72f21).html

PSS-Cluster. 2016. http://www.fof-pss-cluster.eu/about-pss-cluster/

Qu, M., Yu, S., Chen, D., Chu, J., Tian, B. 2016. State-of-the-art of design, evaluation, and operation methodologies in product service systems. Computers in Industry 77: 1-14.

Reim, W., Parida, V., Ortqvist, D. 2015. Product e Service Systems (PSS) business models and tactics e a systematic literature review. Journal of Cleaner Production 97, 61-75.

Rese, M., Karger, M., Strotmann, W-C. 2009. The dynamics of Industrial Product Service Systems (IPS2) – using the Net Present Value Approach and Real Options Approach to improve life cycle management, CIRP Journal of Manufacturing Science and Technology 1(4):279-286.

Rese, M., Strotmann, W.-C., Karger, M. 2009. Which industrial product service system fits best? Evaluating flexible alternatives based on customers' preference drivers. Journal of Manufacturing Technology Management 20(5): 640–653.

Roos, G. 2015. Servitization as Innovation in Manufacturing — A Review of the Literature. In: R. Agarwal et al. (eds.), The Handbook of Service Innovation, Springer-Verlag London 2015.

Sakao, T., Shimomura, Y., Sundin, E., Comstock, M. 2009. Modeling design objects in CAD system for Service/Product Engineering.Computer-Aided Design, 41 (3):197–213.

Schmidt-Bleek, F. et al. 1993: Special Issue, Fresenius Environmental Bulletin. Vol. 2/No 8., pages 407-490, Birkhäuser, Basel, Boston, Berlin.

Schuh, G., Boos, W., Volker, M. 2011. Collaboration platforms to enable global service provision in the tooling industry, Production Engineering, 5, 2011.

Spring, M., Araujo, L. 2017. Product biographies in servitization and the circular economy. Industrial Marketing Management, 60:126–137.

Spring, M., Araujo, L., 2009. Service, services and products: rethinking operations strategy. Int. J. Operat. Prod. Manag. 29 (5), 444-467.

Stahel, W. 1982. The product-life factor. Geneva: Product-Life Institute.

Stahel, W. 1994. The utilization-focused service economy: Resource efficiency and product life extension. In B.R. Allenby & D.J. Richards (Eds.), The greening of industrial ecosystems (pp. 178-190). Washington, DC: National Academy Press. Retrieved July 8, 2008, from: http://books.nap.edu/openbook.php?record_id=2129&page=178

Tietze, F., Schiederig, T., Herstatt, C. 2013. Firms' transition to green product service system innovators: Cases from the mobility sector. International Journal of Technology Management 63(1/2):51-69.

Tischner, U., Vezzoli, C., 2009. Module C: Product–service systems; tools and cases, in: Crul, M., Diehl, J.C. (Eds.) Design for Sustainability (D4S): A step-by-step approach. UNEP.

Tran, T.A., Park, J. Y. 2014. Development of integrated design methodology for various types of product – service systems. Journal of Computational Design and Engineering 1 (1):37-47.

Tranfield, D., Denyer, D. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Tukker, A. 2004. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment, 13 (4): 246–260.

Tukker, A. 2015. Product services for a resource-efficient and circular economy - A review. Journal of Cleaner Production 97: 76-91.

Tukker, A., Tischner, U., 2006a. Product-services as a research field: past, present and future. Reflections from a decade of research. Journal of Cleaner Production 14 (17), 1552-1556.

Tukker, A., Tischner, U., 2006b. New Business for Old Europe. Product-service Development as a Means to Enhance Competitiveness and Eco-efficiency. Greenleaf Publishing, Sheffield, UK.

UNEP. (2002). United Nations Environmental Programme (UNEP). Product–service systems and sustainability. Opportunities for sustainable solutions. Paris: UNEP, Division of Technology Industry and Economics, Production and Consumption Branch; 2002.

van Halen, C., Vezzoli, C., Robert Wimmer, 2005. Methodology for product service system innovation (MEPSS). How to develop clean, clever and competitive strategies in companies. Koninklijke Van Gorcum, Assen.

van Halen, C., Vezzoli, C., Wimmer, R., 2005. Methodology for Product Service Innovation. How to Implement Clean, Clever and Competitive Strategies in European Industries. Koninklijke van Gorcum, Assen, Netherlands.

Vasantha, G., Roy, R., Lelah, A., Brissaud, D. 2012. A review of product-service systems design methodologies. Journal of Engineering Design, 23 (9): 635-659.

Vasantha, G.V.A., Roy, R., Corney, J.R. 2015. Advances in Designing Product-Service Systems. J. Indian Inst. Sci. 95, 429-447.

Velamuri, V., Neyer, A.-K., Möslein, K., 2011. Hybrid value creation: a systematic review of an evolving research area. Journal für Betriebswirtschaft 61 (1): 3 - 35.

Vergragt, P., 2000. Strategies Towards the Sustainable Household, Final Report, SusHouse Project. Delft University of Technology 16.

Vezzoli, C., Ceschin, F., Diehl, J.C., Kohtala, C.2012. Why have 'Sustainable Product-Service Systems' not been widely implemented? Meeting new design challenges to achieve societal sustainability. Journal of Cleaner Production 35: 288-290.

Vezzoli, C., Ceschin, F., Diehl, J.C., Kohtala, C.2015. New design challenges to widely implement 'Sustainable Product e Service Systems'. Journal of Cleaner Production 97: 1-12.

Vezzoli, C., Kohtala, C., Srinivasan, A. 2014. Product-Service System Design for Sustainability. Learning Network on Sustainability. Greenleaf Publishing. 503 p.

Wang, P.P., Ming, X.G. , Li, D., Kong, F.B., Wang, L. Wu, Z.Y. 2011. Status review and research strategies on product-service systems, International Journal of Production Research, 49:22, 6863-6883.

Wise, R., Baumgartner, P. 1999. Go downstream-The new profit imperative in manufacturing. Harvard Business Review, 7 (5):133-141.

Wong, M. Implementation of innovative product service-systems in the consumer goods industry. PhD Thesis, Cambridge University, 2004.

Xing, K., Ness, D. 2016. Transition to product-service systems: principles and business model. Procedia CIRP 47: 525–530.

Yang, M., Evans, S., Vladimirova, D., Holgado, M., Rana, P.2015. Product-Service Systems as Sustainable Business Models: theoretical and empirical findings, Global Cleaner Production & Sustainable Consumption Conference, Barcelona, Spain.

Zhang, F., Jiang, P., Zhu, Q., Cao, W., 2012. Modelling and analyzing of an enterprise collaboration network supported by service-orientated manufacturing. Proceedings of the Institute of Mechanical Engineering Manufacturing 226 1579-1593.

Zhu, Q.Q., Jiang, P.Y., Huang, G.Q., Qu, T., 2011. Implementing an industrial product- service system for CNC machine tool. Int. J. Adv. Manuf. Technol. 52, 1133-1147.

CAPÍTULO IV

The main implications and contributions of this Chapter to this thesis were the following:

- Was possible to comprehend the factors involving the SPSS transition in manufacturing SMEs.
- Was found the qualitative research techniques and the most functional tools most frequently employed in the studies on SPSS transition in SMEs.
- Identified internal barriers associates with intrinsic characteristics of SMEs become still more sensitive during the SPSS transition (e.g., limited financial resources, the lack of competences, follower mentality, resistance to change etc). These findings are similar to findings on eco-innovation practices in manufacturing SMEs (Chapter 1 and 2).
- The main barriers related with the novelty of SPSS business models require new attitudes to SMEs (e.g., change mind-sets from product ownership to use, replace value of exchange by value in use involving long term relations, lack of understanding of SPSS concept).
- Particularly the lack of models and methods guiding this transition was found as being one of main barriers related with the novelty of SPSS business models.
- Was found that the combination between service engineering systematic and structured tools with Business Model Canvas or Design Thinking approaches results in more effective methods supporting transition and helping to internalize some required competences in SMEs (Xing and Ness, 2016; Orloff and Heinz, 2015; Pardo, 2012).
- Based on the results from literature, an innovative Matrix supporting the decision making process by SMEs during the transition process to SPSS was proposed and incorporated in the method.
- Two corollaries emerged from results:
  Corollary 1: The transition process towards SPSS must be made incrementally instead radically.

Corollary 2: The engagement of manufacturing SMEs in partnership and networks to develop the SPSS offers has potential to minimize the competence gaps and enable more innovative, complete and competitive value proposition to customers.

- This chapter offer a deep understanding on the SPSS diffusion in manufacturing SMEs and a comprehensive scientific support to trigger this transition.

5 Artigo 4: Sustainable Product-Service Systems in Small and Medium-sized Enterprises: State of the art and Challenges

Abstract

Sustainable Product-Service System (SPSS) represent a promising approach based in a Triple Bottom Line perspective of sustainability. However, its adoption is still very limited evolving significant barriers. Besides, this emergent topic has been discussed mainly in large company's context, turning very limited and in immature stage the current framework in Small and Medium-sized Enterprises (SMEs). Thus, considering the significance of SMEs to the global economy and their intrinsic difficulties, the purpose of this study is comprehend the factors involving the SPSS transition in manufacturing SMEs. A systematic literature review of the past two decades (1995-2016) was conducted based on review protocol. Findings show that qualitative research techniques and tools, case study and workshops to validation of artefacts are the most frequent strategies employed by literature. Results reveal internal barriers associates with intrinsic characteristics of SMEs that become still more sensitive during the SPSS transition (e.g., limited financial resources, the lack of competences, follower mentality, resistance to change etc). As well as, barriers related with the novelty of SPSS business models requiring new attitudes to SMEs (e.g., change mind-sets from product ownership to use, replace value of exchange by value in use involving long term relations, lack of understanding of SPSS concept), and particularly the lack of models and methods guiding this transition. The main drivers found are related with economic motivation, need of differentiation, create market opportunities, meet customer' need and sustainability. An innovative matrix supporting the decision making process by SMEs during the transition process to SPSS was proposed. Furthermore, suited tools to conceptual design, stimulation and management of transition also emerged. Finally the mains research gaps and the directions for future research to advancing in this field are highlighted. The results provide a structured overview of SPSS diffusion in manufacturing SMEs and a comprehensive scientific support to trigger this transition. Research insights extend and enrich the literature on SPSS focusing on the challenges of servitization in SMEs. As practical implication, SME' managers, policy makers, academics and PSS community can benefit in order to successful implement SPSS in SMEs.

Keywords: Product-Service System. Servitization. Sustainable PSS. SME. Small and Medium-sized Enterprises.

5.1 Introduction

Sustainability has become one of the key factors for long-term business success (Yang et al., 2017). In addition, the concept of developing sustainable products-services is evolving as a key element of Cleaner Production (Maxwell and van der Vorst, 2003). Many manufacturers today are striving to offer high value-added Product-Service System (PSS) due to increasing competition and environmental pressure. However, PSS design activities face a variety of challenges such as a high level of customization, hidden requirements in product use phase, potential conflicts of design attributes and internal complexity of service processes (Song and Sakao, 2017). Besides, although PSS domain emerged from the sustainability field, its practical development is not matured (Vasantha et al., 2015).

Sundin et al. (2015) state that originally the PSS was developed as a more sustainable alternative to traditional product-sales, especially through better and more intensive use of materials. By shifting from traditional offer to an integrated solution of product-services, it was assumed that PSS could reduce the environmental impact and provide benefits for the PSS provider and the consumer in economic and social ways. However, currently there is in the literature the understanding that the sustainability is not an intrinsic characteristic of PSS business models (Doualle et al., 2015; Pigosso and McAloone, 2016; Boucher et al., 2016). Several recent studies have discussed that the environmental performance of PSS can indeed be worse if compared to traditional products offer (Kjaer et al., 2016; Pigosso and McAloone, 2016; Barquet et al., 2016b).

In this direction, studies have demonstrated that PSS business models may have a negative effect on the environmental issues resulting only in economic benefits (Barquet et al., 2016a; Halme et al., 2004; Tukker, 2015; Doualle et al., 2015). Pigosso and McAloone (2016) stated that, despite their substantial potential for enabling increased environmental performance, PSSs are not intrinsically environmentally sustainable. Boucher et al. (2016, p. 1) recently corroborated: “The PSS concept was initially considered to be a promising initiative to influence on sustainable production and consumption patterns. But it is now stated that PSS do not necessarily lead to sustainable solutions”. Consequently, abroad this discussion, a perspective defined as “Sustainable Product-Service Systems (SPSS)” has received attention from academy.

SPSS is “an offer model providing an integrated mix of products and services that are together able to fulfil 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” (Vezzoli et al., 2015, p. 2). Barquet et al. (2016a, p. 436) defined SPSS as “an approach to achieve benefits in the three dimensions of sustainability”. SPSS aimed at maximizing environmental and social performance in products, services or PSS offer (Maxwell et al., 2006). Therefore, based on these definitions, differently by traditional product-service system assumptions, more focused on customer’ needs, economic and eventually environmental results, SPSSs are intrinsically embedded in a Triple Bottom Line perspective of sustainability. SPSS offer is effectively a win e win proposition: environmentally, socio-ethically and economically sustainable at the same time (Vezzoli et al., 2015). However, although SPSS innovations represent a promising approach to sustainability, also its adoption is still very limited because in most of the cases are radical innovations, involving significant corporate, cultural/behavioural and regulatory challenges (Ceschin, 2013; Vezzolli et al., 2015).

The literature shows several evidences of which the transition towards SPSS is not an easy journey and that many difficulties hinder a sustainable servitization to large and specially to Small and Medium-sized Enterprises (Vezzoli et al., 2015; Salazar et al., 2015; Kjaer et al., 2016; Pardo et al., 2013; Orloff and Heinz, 2015). A possible reason is that there are significant differences in innovation business models between large companies and SMEs. Policies as well as theories and instruments suited for large companies do not necessarily lead to successful outcomes within an SME. Another disadvantage is regarding the current research framework accumulating. The most part of literature focus mainly on large and often multinational companies, overlooking the significant contribution from SMEs. At least 80% of all global enterprises are considered SMEs (Moore and Manring, 2009). According to European Commission (2011) SMEs represent with over 99% of European enterprises and around two-thirds of European employments. Therefore, due the significance of SMEs, specifications and key directions towards SPSS business models diffusion for SMEs are very necessary.

Besides, considering specifically some intrinsic characteristics of SMEs (Bos-Brouwers, 2010), the SPSS transition can be still more difficult. First, considering the financial aspects, the failure of innovation projects, as a new SPSS offer, may be disastrous to SME due their economic constraints. Difficulties attracting venture capital and investments and the high fixed costs for technological investments also can be critical for scaling up new SPSS business models. Second, on the owner/manager perspective, the poor managerial skills (planning, inadequate delegation, lack of functional expertise or support), the high dependency on persons for survival and the lack of formalized planning, can turn more difficult the implementation of SPSS offer. Third, the difficulties attracting skilled personnel and the harder to update technological knowledge also may affect a successful SPSS due the new competences' need (i.e. design and sustainable competences). Hence, considering these difficulties and the economic significance of small business to global economy, it is necessary comprehend which strategies have potential to mitigate these core disadvantages faced by SMEs in order to obtain a more fluid transition towards SPSS business models.

Due fact the SPSS still is an immature research topic and directed to large companies, by consequence there is a clear gap in literature regarding its implementation and diffusion specifically in SMEs context. The literature focused on this domain is scarce and, as a result, the operational deployment at the concrete level of the industrial SMEs economy are very limited (Clegg et al., 2017; Boucher et al., 2016; Nada and Ali, 2015; Pardo et al., 2012). To illustrate this aspect, a search by strings "Sustainable Product-Service System & SME" in Title field in Scopus database, returns only one single result. Hence, the hypothesis considered is that the debate of SPSS in SMEs is in a very immature research stage. In this context, this research focuses specifically on capital goods manufacturing SMEs.

Therefore, considering that the existing background for SPSS transition in SMEs are fragmented and insufficient to support a fluid transition process, in order to fill this research gap, the purpose of this study is to comprehend, what are the factors involving the transition to SPSS within SMEs into practice? To fill this gap was performed a systematic literature review (1995-2016) in the mains scientific databases through the analysis on the follow objectives: (i) identify the mains previous authors and studies in this topic; (ii) identify frequent methods and tools applied in transitions to SPSS supporting SMEs; (iii) consolidate the benefits, barriers and strategies to overcome or mitigate these barriers in SMEs; (iv) discover new gaps in available literature and identify interesting topics for further development in this research field. This propose enable advance on understanding of implementing SPSS business models in SMEs through a systematic literature review.

The relevance of our research is identify and presented new insights to SME' managers, policy makers and academic in order to successful implement SPSS. Another contribution is that our paper extends the current theory framework on PSS and SPSS in SMEs and drive new researches avenues to this domain. Our study provides a structured and comprehensive review of literature and several insights emerged from these results. Corroborating the importance of our study, recently Reim et al. (2015, p. 62) stated "[…] there is an increased need to synthesize the findings of existing studies and provide directions for future research on the important topics of PSS business models and tactics." This occurred because the rapid growth of the researches in this field, contributes to problems associated with accumulating and systematizing research findings. The remainder of this paper is organised as follows. Section 2 reviews the literature and mains definitions. Section 3 presents the research method and protocol of systematic review carried. Section 4 shows the results. Section 5 discusses the research results and their management and scientific implications. Finally, Section 6 presents the conclusions and keys research directions.

5.2 Theorical background

SMEs can be defined as independent businesses involved in the delivery of goods and services in a wide variety of industries and sectors. The term "SME" is used to group together businesses based on their size. This is measured financially and/or by the number of people employed in the business. The definition varies from country to country. For example, the maximum headcount for an SME in Mexico is 100, whereas in Denmark and Brazil it is 500 employees (Mitchell, 2014; Berisha and Pula, 2015).

Nowadays, SMEs are the engine of the European economy. They drive job creation and economic growth and ensure social stability. In Europe, SMEs make up 99% of the millions of businesses that are operating within the member countries, and account for 67% of total employment. SMEs also stimulate an entrepreneurial spirit and innovation throughout the EU and are thus crucial for fostering competitiveness and employment. In EU Small enterprises are defined as enterprises that employ fewer than 50 persons and whose annual turnover or annual balance sheet total does not exceed EUR 10 million. Medium-sized Enterprises are defined as enterprises that employ fewer than 250 persons and either have an annual turnover that does not exceed EUR 50 million, or an annual balance sheet not exceeding EUR 43 million (European Comission, 2016).

A World Bank study, known as “MSMB Country Indicators” reveals that out of 132 countries covered in the study, 46 of them define SMEs as businesses with fewer than 250 employees. Each country exercises the freedom to define SMEs specifically, as aftermath of which today’s SME theory counts with a great host of definitions (Berisha and Pula, 2015).

For example, in as emergent economy such as Brazil, Micro and Small companies represent 60% of Gross Domestic Product and 85% of jobs. Are classified as Small industrial companies from 20 to 99 employees with revenue maximum to R$ 3.6 million annually. Medium-sized companies have 100 to 500 employees (Sebrae, 2015). In comparison with their counterparts in Asian and European countries, dynamic entrepreneurs in Latin America lag behind in dynamism, but they act in similar ways. Therefore, policy recommendations and exchange of experiences are equally useful to SMEs in all regions (OECD, 2010).

It is recognized that SMEs need to improve their environmental performance in line with EU targets (European Union, 2011). However, the most available research on innovation and corporate sustainability applies to large companies, whereas the innovation process for SMEs is different (Bos-Brouwers, 2010). Many researchers reported very interesting experiments in large enterprises, typically specialized in functional goods production, while only few researches have been performed for SMEs (Tonelli et al., 2009). The mains differences between large and SMEs are summarized (Table 1).

Table 1: Mains differences between SMEs and large enterprises

SME	Large enterprises
Dominant role of the entrepreneur/owner	Delegated management control between board of directors and shareholders
Resource poverty (capital, time, knowledge and skilled personnel)	Economy of scale, resource abundance
Flexible organization capacities	Bureaucratic rigidity
Focus on short term	Focus on mid to long term
Strong local/regional focus and customer needs orientation	Strong (inter)national focus and looser ties with customers
Low degree of formalization	High degree of formalization

Source: Bos-Brouwers (2010).

Normally, SMEs are characterized as a type of industry strongly oriented to economic results and with tight financial budgets to introduce new projects, as a SPSS offer, in areas that are not directly related to production/manufacturing and that do not show savings in a short term perspective (Ness, 2009). Besides these differences (Table 8), there is still a lack of specific and practical servitization literature devoted to helping SME owners and managers to compete through PSS delivery. The existing literature is still too generic and insufficiently supported by empirical evidence (Clegg et al., 2017). Pardo et al. (2013) also affirm that there are only few examples of these systems to study in practice and even less related to SMEs. In addition, some of the barriers for developing sustainable operations in SMEs are also barriers to developing SPSS. More efficient firms with higher innovation capacity, flexible operations and better communications skills are part of the benefits of a SPSS but are also part of the competences required for PSS (Pardo, 2012).

Indeed service growth in product firms has become one of the most active service research domains, to the point that it has been identified as a strategic research priority. This domain is concerned with product firms shifting from developing, manufacturing, and selling products to innovating, selling, and delivering services (Kowalkowski et al., 2017). Nonetheless several constraints are faced by SMEs. While exploratory research shows that small firms can successfully pursue service growth and may in fact have advantages over larger competitors (Kowalkowski et al., 2013), the study further suggests that small firms are less likely to have a general recipe for service success. Larger firms are more likely to have the organizational slack and market power that are favourable conditions for success (Kowalkowski et al., 2017).

Paiola et al. (2012) also highlighted the following obstacles in manufacturing SMEs original equipment manufacturer (OEMs), related to: (i) Customer: addressing more complex customer needs is beyond the competence of small and medium OEMs; (ii) difficulties in visioning, mobilizing and orchestrating other partners to participate in addressing more complex customer needs; (ii) Financial: financial risks and resources are too high for formulating strategic responses for the sensed service opportunities; basic cost accounting systems concentrating on fixed costs and not activity- related costs; personnel compensation is relatively simple through basic cost structures; (iii) Strategy and market: concentration on market niches protecting OEMs from high competitive rivalry and new entrants; strategic responses still concentrate on technological superiority of the equipment; portfolio working limits the concentration on specific tasks; (iv) Competences: lack of critical mass needed to run a separate service organization in a profitable way; ad-hoc recruitment limits recruiting and training of service competencies; job enlargements and portfolio working limit dedicated job profiles for developing, selling, and controlling services; (v) Network: suppliers often bypass smaller OEMs and sell spare parts directly to end-customers; logistic vendors offer high performance level only to strategic partners; local distributors are not only partners, but also competitors in the service provision; (vi) service transition: reconfiguration is more an entrepreneurial challenge; service oriented values and behaviours would benefit from flexibility and entrepreneurship; separating product and service business increases coordination costs and boosts complexity; size of the companies limited requirements for demand-forecasting.

Paiola et al. (2012) confirm that it is not easy for manufacturing SMEs to follow the advice of Oliva and Kallenberg (2003) and Raddats and Easingwood (2010) to enter the service market by way of the installed base. Manufacturing SMEs generally sell through distributors and have limited access to their installed equipment. It is not easy for smaller firms to develop a service strategy leveraging on the installed base (Paiola et al., 2013).

However, although SMEs faced several disadvantages compared with large manufacturing firms, they also enjoy advantages, including a more entrepreneurial culture, a more flexible and agile organization, greater proximity to customers and partners, and better interfirm adaptability, which they should recognize and exploit (Kowalkowski et al., 2013). Table 2 complements the set of advantages and disadvantages to SME.

Table 2: SMEs Advantages and Disadvantages

Advantages	Disadvantages
Flexibility of organization	***Financial***
Less bureaucratic Responsiveness to changing circumstances (technology and market) Internal communications faster and more efficient	Difficulties attracting venture capital and bank investments Failure of innovation projects may be financially disastrous High fixed costs for technological investments and start-up
Owner/manager	***Owner/manager***
Dynamic, entrepreneurial Horizontal leadership style Direct role in innovation as ideas generator	Poor managerial skills (planning, inadequate delegation, lack of functional expertise or support) Dependency on persons for survival Lack of formalized planning
	Labour
	Difficulties attracting skilled personnel Harder to update technological knowledge

Source: Bos-Brouwers (2010).

As a result, the SME must explore this core of advantages in order to minimize their own disadvantages and the strong points of large enterprises. Thus, is possible conclude that little is known about service infusion in SMEs (Kowalkowski et al., 2013) and the discussion about how smaller firms address the transition from PSS is at an early research stage (Paiola et al. , 2013). Furthermore, the recent research and practice show that business model innovation is a promising approach for improving sustainability in manufacturing firms (Yang et al., 2017).

5.3 Research Method

To advance and extend the current research framework on SPSS transformation in manufacturing SMEs, driving new researches avenues to PSS field, the present study consisted of a systematic literature review. The specific focus in on researches related to SPSS transformation in capital goods manufacturing SMEs and its operational tactics. An advantage of systematic literature review is provides understanding of the state of the art of the research domain and aids in the identification of useful knowledge (Dresch et al., 2015; Tranfield and Denyer, 2003; Moher et al., 2009).

In this sense, we adopted the research protocol suggested by Dresch et al. (2015) and have detailed the structured stages adopted as following.

Step 1: Planning research process. *Definition of the issue and conceptual framework*. Our research aims to comprehend what are the mains factors involving the transition process to SPSS in manufacturing SMEs context into practice. *The research question*. The research question of this study is, what are the factors involving the transition process to SPSS within SMEs into practice? *Work team*. The stages of systematic literature review process were performed by the authors of this study.

Step 2: Identifying publications and applying practical screening. *Search strategy, keywords, period, databases, inclusion/exclusion criteria and eligibility/coding.* For the keyword and Boolean operator's definition, initially a preliminary analysis was performed in previous systematic literature review papers focused in PSS domain. A initial list of keywords was extracted from following papers: *'State-of-the-art of design, evaluation, and operation methodologies in product service systems'* by Qu et al. (2016), *'Product e Service Systems (PSS) business models and tactics - a systematic literature review'* by Reim et al. (2015), and the *'Product-service systems: a literature review on integrated products and services'* (Beuren et al., 2013) and '*State-of-the-art in product-service systems'* (Baines et al., 2007). As result, an initial set of keywords frequently used by academics in PSS domain could be consolidating.

Next, a preliminary search combining the keywords PSS, 'Sustainable Product-Service system, SME and Small and Medium-sized Enterprises was realized in Scopus database and in the "Journal of Cleaner Production" aiming to identify keywords specifically related with 'Sustainable Product-Service system' domain. This choice was observed because Scopus is a relevant scientific database and JCLP is cited in previous studies (Tukker, 2015) as leader in terms of quality and number of publications in PSS. Thus, others keywords were identified and added. Due the existence of limited literature on SPSS in SMEs identified, we decide included a broad keywords list in the step of full search process, aiming to capture all papers specific on SPSS transition in manufacturing SME available in scientific databases.

Table 3: Search strings and results

Search strings	Total in Scopus	Total in Web of Science
Sustainable product-service system	3	-
Product-service system	13	1
Product-service	62	6
Servitization	8	-
Sustainable Service	-	-
Industrial product service system	-	-
Service engineering	-	1
PSS	11	-
IPSS	-	-
Service-dominant logic	5	-
Servicification	-	-
Functional product	1	-
Functional product development	-	-
Integrated product service engineering	-	-
Integrated product service offering	-	-
Functional sales	-	-
Dematerialisation	1	-
Service infusion	-	-
Product-to-service	-	-
Post mass production paradigm	-	-
Service-oriented	66	4
Integrated solutions	10	-
Product bundling	2	-
Hybrid offerings	-	-
Sharing economy	-	-
Shared economy	-	-
Circular economy	4	4
Total	**186**	**16**

Finally, to conduce the final search process, the combinations of keywords (Table 3) with '*SME*' and '*Small and Medium-sized Enterprises*' were performed in the field '*Title, Abstract and Keywords'* of Scopus and ISI Web of Knowledge (WoS) databases (Table 3). To exemplify, one of several combinations performed to screening was the following: 'Sustainable Product-Service System' & 'SME'. The WoS and Scopus coverage differ the most in Engineering, Natural Science and Arts/Humanities and not necessarily index the same journals (Mongeon and Hus, 2016). Scopus database is one of the largest multidisciplinary including social science and engineering studies, abstract and citation databases of peer-reviewed literature. Its covers research from several publishers (i.e. Elsevier, Emerald, Springer, and Wiley, among others). Because this database covers peer-reviewed multidisciplinary research studies, it was certain to find a good number of studies (Reim et al., 2015). Complementary, additional records also were identified through other sources. In this case, an internet search and Google Scholar was conducted to locate reviews studies such as, PhD thesis or even peer review papers no obtained by databases, using the combinations of keywords adopted in the databases search.

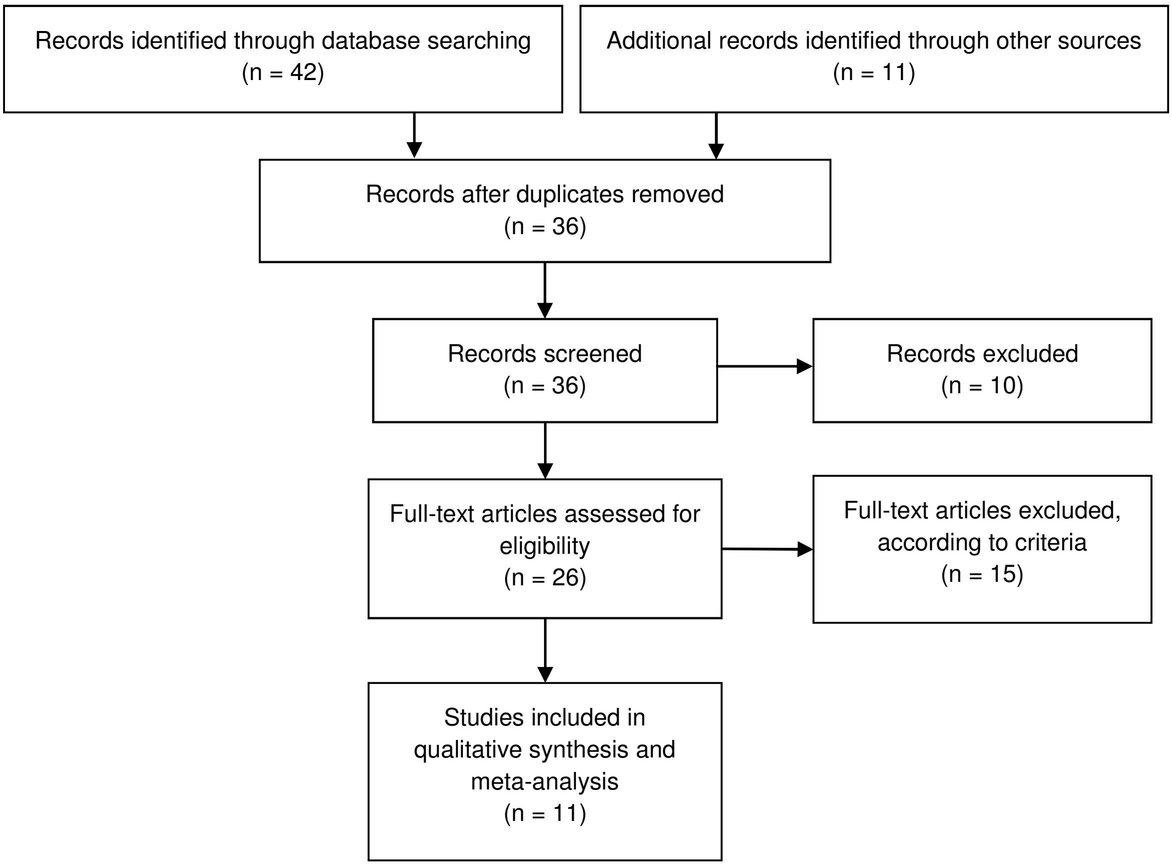

Fig. 1. Synthesis of research process.

The use of Scopus and Google Scholar in addition to WoS contribute to a more accurate assessment. Moreover, types of citing documents significantly differed between disciplines thus suggesting that a large range of academic non-journal publications are not indexed in WoS but are accessible through Google Scholar (Mongeon and Hus, 2016). Finally, article's most cited on references of papers also were analysed and if considered adherent with inclusion/exclusion criteria were included to analyses.

Step 3: Applying theoretical screening criteria. *Search period.* The search period considered was between January/1995 and December/2016. The In this stage, the search process adopted (Moher et al., 2009) is detailed (Fig. 1). *Inclusion and exclusion criteria*. The eligibility criteria adopted for inclusion of studies for full analysis were as follows: (i) papers investigating the transition process to SPSS specifically in capital goods manufacturing SMEs; (ii) proposing artifacts (i.e.

methods, models or tools) on this topic; (iii) papers clearly demonstrating practical evidence/results on SPSS deployment in capital goods manufacturing SMEs; (iv) studies in English language. According to Mongeon and Hus (2016) English has a dominant position in sciences and is overrepresented in the scientific knowledge. Besides, the *Exclusion criteria* adopted were: (i) studies with high quantitative or statistical bias making it difficult capture insights; (ii) theorical and conceptual papers; (iii) papers investigating the transition into large companies or in non-manufacturing SMEs (e.g., software, tourism, commercial, sharing models); (iv) we used only formal literature, does not including books, 'grey' research reports, etc (v) studies demonstrating low methodical rigor.

Step 4: Final filtering and process analysis. The data collected from each study were used to identify relevant aspects related to the identified factors and how they could impact SPSS transition and sustainability performance in manufacturing SMEs. To perform the analysis of these studies, an open coding content analysis technique was employed aiming certified if the publication consider the sustainability perspective on transition to SPSS. The search yielded eleven select studies, revealing the absence of researches in this topic. During the process analysis developing, notes and headings were synthetized in a spreadsheet in association with our research goal. After presenting the main metadata results and descriptive analyses, the synthesis based on configurative analyses (Gough, Oliver and Thomas, 2012) was considered. Open questions in literature review studies designed to explore a topic more broadly are best answered by means of a configurative review. In configurative analysys the review questions tend to be answered with qualitative data gathered from more heterogeneous primary studies, which are interpreted and explored throughout the review to generate and explore the theory (Gough, Oliver and Thomas, 2012; Dresch et al., 2015). The results are discussed in depth in the next sections.

5.4 Descriptive findings

5.4.1 Contextualizing PSS and SPSS state of art

Initially we compare the state of art of PSS, SPSS and both applied in SME context. Table 4 exemplifies the total of published articles and the respective matching keywords searched individually in the title, abstract and keyword field in

Scopus (status in 10/fev/2017). We exemplify the Scopus results to avoid duplication of studies between databases.

Table 4: Number of publications per year *versus* keywords

Year	'product-service system'	'product-service system & SME'	'sustainable product-service system'	'sustainable product-service system & SME'
2000	1		1	
2001	5		2	
2002	3			
2003	12		2	
2004	7		1	
2005	10			
2006	28		3	
2007	24			
2008	30	1	2	1
2009	71	1		
2010	91		3	
2011	111	1		
2012	118	1	4	1
2013	163	2	4	1
2014	191	3	5	
2015	237	1	18	
2016	220	3	13	
Total	**1322**	**13**	**58**	**3**

By analysis in Table 4, relevant findings can be highlighted. First, is possible verified an increasing number of published studies from 2010 regarding 'product-service system' field. Around 85% of PSS' studies were published from 2010. The number of publications doubled from 2011 to 2015. Furthermore, a very recent increase interest by 'sustainable product-service system' topic is past two years is clearly evidenced. Regarding these results (58), still is possible affirm that the literature is limited. Third, little amount of studies specific on 'product-service system & SME' and 'sustainable product-service system & SME' confirm that the theoretical background on PSS and mainly SPSS in SMEs context is very limited (Clegg et al., 2017; Boucher et al., 2016; Pardo et al., 2012). This very recent increase interest by SPSS in SMEs in past years confirming that this field is in infancy stage and fragmented.

5.4.2 Tactics towards SPSS transition in SMEs

In this section, outcomes were extracted from selected studies investigating the transition process to obtain SPSS in manufacturing SMEs. Initially, due the increasing interesting on the topic, results shows that half of studies were published from 2014. The most distant paper was published in 2009 (Tonelli et al., 2009). Thus, the recent date of publications of all studies corroborated the advocated hypothesis of limited and fragmented literature in this domain as our previous findings. Still, by analysing the content of the major contributions identified, it was found that scholars tend to discuss the transition towards SPSS in manufacturing SMEs adopting four distinct categories of tactics.

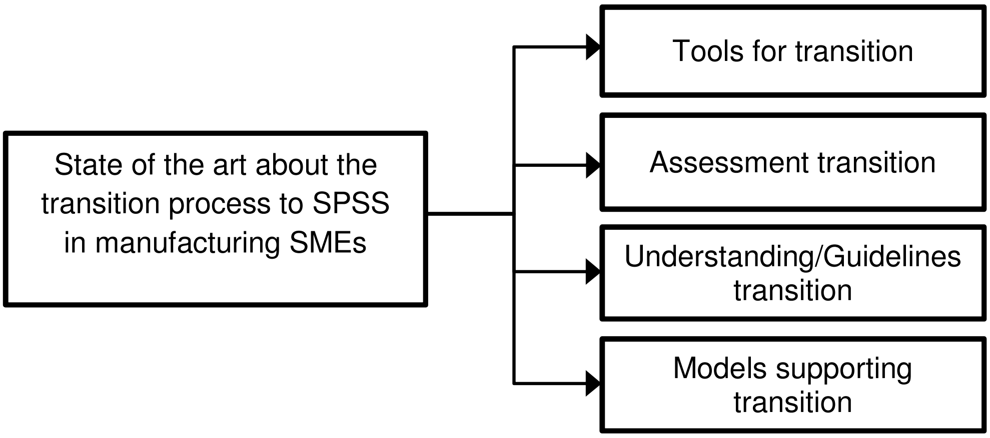

Fig. 2. Tactics categorized in systematic review.

On the ‘Understanding/Guideline transition’ category of studies, Pardo et al. (2012), for example, focused on understanding how the integration of product and service design and the use of Information and Communication Technologies (ICT) can contribute to identify opportunities to develop SPSS involving leather manufacturing SMEs. Xing and Ness (2016) establishes a value proposition for product-service system transition with a set of key guidelines and practical orientations to successful transition. This research examining a SME of cleaning equipment’s. Also, transition road map is established to assist firms make the shift by taking the necessary steps and to understand the requirements and potential benefits associated with each step along the way. The study by Orloff and Heinz (2015) investigated what are promoting factors for long-term success and up scaling of SPSS in manufacturing SME practice and how Design Thinking can contribute to SPSS development. For evaluate how Design Thinking can contribute to SPSS development, it also could be classified in category ‘Tools applied for transition’.

Salazar et al. (2015) investigated a manufacturing SME providing PSS offering for environmental sensor applications, how developers combine different approaches to eco-designed product-service system. Rapitsenyane (2014) explores effective and contextually appropriate means through which manufacturing SMEs can create competitive advantage through design and SPSS. The study identified factors relevant for manufacturing SMEs in Botswana to explore SPSS as a competitive business strategy, by analysing the competitiveness experiences of leather manufacturing SMEs. In this same line, Pardo et al. (2013) also identify those organizational aspects that can contribute to develop SPSS in leather SMEs in Colombia. Finally, Orloff and Heinz (2015) investigated what are promoting factors for long-term success and up scaling of SPSS in SME practice and how Design Thinking can contribute to SPSS development.

Regarding to category ‘Models to support transition’ useful artifacts are proposed by literature. Tonelli et al. (2009) developed and tested the framework Analysis, Development, Verification, and Proposal (ADVP) elaborate for PSS assessment and implementation. They also present the results and learning from the action research conducted in the health-care SME sector that experienced a PSS. Lelah et al. (2012) proposes a new model for activities and processes in firms collaborating together in a network based on SME-Integrator collaboration delivering product-service system. This model can help understand the process and facilitate the organization of the network in order to reap the benefits. The case of glass waste collection in the French project SensCity was analysed.

Pardo (2012) explore new possibilities to design SPSS in SME taking advantage of possible contributions coming from the integration between design and Information and Communication Technologies. A comprehensive model to design SPSSs involving SMEs is proposed and validates by mixed research methodologies and stages. Regarding the tools applied for transition, ‘scenarios’ tool was adopted as a methodological tool to help support decisional processes when moving towards SPSS in manufacturing SMEs (Lelah et al., 2014). To assessment of SPSS transition, sustainable indicators were defined from literature and validate with three SMEs in different phases, towards providing PSS in Sundin et al. (2015).

Around this debate, a complementary aspect that helps to comprehend the scope of these practices is the background of academics leading the studies. The most of them are originally of research groups in Industrial Engineering or from Design area. Design discipline is recognized by emphasis in system design focusing human interactions. While Industrial Engineering area is highlighted by systematic/pragmatic and oriented value proposition vision of systems. In or point of view, the integration of two areas have potential to achieve more effective SPSS models. This outcome is reinforced by Tukker (2015) when conclude that the literature on integration of tools in the main detailed PSS design methods that are available, is not yet mature or that tools are still lacking, potentially leading to a lack of emphasis on requirements that should drive PSS design. Our findings still showed that this actual problem in PSS field postulated by Tukker appear more potentialized in SPSS transition into SMEs due the lack of consolidated methods to small business.

Finding shows that research efforts in develop artifacts (i.e. models, methods, instantiations and constructs) are a positive aspect. According to Design Science Research definitions, method is a set of steps used to perform a task and instantiation is the realization of an artefact in its environment and a model is a set of propositions or statements among constructs that expresses relationships and is a representation of how things are (March and Smith, 1995). In our point of view, the proposition of new methods, in this early stage of research on SPSS in SMEs domain, is a relevant and necessary step to advance in innovative SPSS methods oriented to manufacturing SMEs. Still it is possible conclude that due fragmented and early research stage in this topic, there is no an clear research direction (i.e. type, segment, B2B or B2C, leader research group).

5.4.3 Business context and region

This section discusses the environmental business and the localization of selected studies. Lelah et al. (2014) investigated two SMEs, both in B2B from Loire region in France. Company A is engaged in a long-term servitization process. This unity of analysis can be characterized by the transformation of the offer, the business model, the internal skills and the organization of the company. This firm manufacture shower head to private and public customers of healthcare institutions (i.e. hospitals, clinics). It is a very common product, low added value and no pressing needs for a sustainable approach because of the low cost effect. SME A also faced effects of globalization and low cost offers (China) and difficulties convincing clients of the sustainable interest of the PSS. Company B has developed to Quarry Production Plant, a B2B product which can be more efficient with a PSS offer, turning the processes of the client faster, easier and cheaper. This company faces difficulties related to the ownership of the product by customers, problems to determine the offer and establish contracts, a quality certification required for the product and regulatory development of a new market.

Sundin et al. (2015) investigated the context of three industrial SMEs of French project ServINNOV. One provides compressed air, hydraulic and electricity, other provides equipment to electrification and automations for quarry, and the last supply sanitary water to health sector. Theorical and empirical schemes were applied to obtain sustainable indicators to guide the SPSS transition. Salazar et al. (2015) analyse how developers combine different approaches to eco-designed PSS. The research occurs in Azimut Monitoring, a French SME providing PSS offerings for environmental sensor applications. The analysed firm constantly looks towards innovation and technical and environmental improvement of their offers and theirs clients are airport facilities, urban administrations, building facilities etc.

The model proposed by Lelah et al. (2012) verified the glass waste collection in the French project SensCity. In SensCity the Machine-to-Machine network covers the city supporting classical urban public utility services and enhances new services using ICT backbone, bringing together SMEs that formally provided vertical services with a telecom operator-integrator. In other research on governmental project, 38 Colombian industrial SMEs engaging in the Project MiPYME Digital, supported by Colombian Ministry of ICTs were investigated in Pardo et al. (2013). This program of assistance to encourage the adoption and use of ICTs in SMEs, jointly finances, with ICT's suppliers, projects to implement ICTs in SMEs from diverse industrial sectors. Pardo (2012) and Pardo et al. (2012) also explores SPSS in leather manufacturing Colombian SMEs participating in this project. All SMEs work with the same process and their year schedule is determined by the commercial fairs in the country. This same type of SME is analysed in Botswana (Rapitsenyane, 2014). In this study, the competitive advantage of the SPPS to manufacturing SMEs was verified with 18 leather SMEs and workshops with 3 SMEs (leather bag, shoes and furniture manufacturer).

Tonelli et al. (2009) analysed the case of an Italian SME operating in the national and international market of non-woven materials for medical and extra-medical applications (surgical kits). It is a family owned business, open to changes, which relies its competitiveness on flexibility, quality and propensity to innovation. The research occurred after the Global Service project has been carried out in about one year with participation of firm. Orloff and Heinz (2015) analyse one 43 years history German company, DBL Marwitz GmBH, a workwear-leasing manufacturing SME in B2B contracts. It is an awarded and sustainability-oriented SME, successfully operating a PSS business model on the long-term. Marwitz operates in a network of seventeen associated but independent family-businesses.

Xing and Ness (2016) investigated the transition of Soniclean, an Australian SME that produce and supply specialized ultrasonic cleaning equipment and products. The firm owns patents for key cleaning technologies and develops energy-efficient machines for end users in manufacturing, food and healthcare industries. The prices of machines range from under 1.000 Australian Dollars per unit until. 60.000 Australian Dollars and the SME have been including value-added services tailored to customers' needs and products' functions.

On the whole, by analysing the content of empirical studies, it was found that scholars tend to discuss SPSS models and implications basically by two forms: in the context of governmental projects focused in SMEs or by independent studies by research groups. Regarding to governmental projects, EU funded projects evidenced be a fruitful environmental to conduct empirical investigations. This occurs because a relevant part of studies are resulting of EU funded projects. Both funded projects and independent studies are generally conducted by researches of same country.

None research project involving the results of collaboration of different countries and academics comparing regional similarities and divergences was identified. This can be an important research opportunity in order to advance in theory-building on SPSS transition. France in particular, is highlighted by studies in this domain. Studies in context of in development economies and in of low-income countries such as Colombia and Botswana also were identified. By and large, the set of all selects publications involving 72 SMEs in different regions around the world. This relative small overall sample reinforces the recent interest by SPSS transition phenomenon in capital goods manufacturing SMEs. More evaluations in industries environments could provide more detail concerning the weaker dimensions and help to identify the SPSS design needs. Furthermore, collaboration between academic researchers and industrial practitioners is vital to ensure and encourage the applicability of the proposed methodologies in industry (Vasantha et al., 2012).

5.4.4 Research techniques and tools supporting SPSS transition

Initially the comprehension of research procedures adopted suggest be similar between studies and qualitative investigation is the dominant approach adopted. For example, theoretical exploration of literature supporting case studies (Xing and Ness, 2016; Sundin et al., 2015; Lelah et al., 2014). Some studies also applied case studies to validate proposed models (Lelah et al., 2012). Salazar et al. (2015) use single case study in a SME to comprehend how developers combine different sustainable approaches to eco-designed PSS. Besides case study combined with different qualitative research methodologies is adopted. Orloff and Heinz (2015) use single case study, semi-structured interviews, workshops and experts feedbacks in order to identify factors for long-term success and up scaling of SPSS in SMEs. Exploratory study, action research and case study unique were found in Tonelli et al. (2009).

Multiple case studies combined with qualitative research also are presents. Pardo et al. (2012) adopts theoretical results from literature review to develop a transition SPSS model, following by exploratory survey with 38 SMEs from different industries and semi-structured interviews carried out with owners or general managers in 16 leather SMEs. Similar approach can be found in Pardo et al. (2013) and internet survey is added to data collection (Pardo, 2012). Rapitsenyane (2014) use Delphi study with 9 experts, case study with 18 leather SMEs, and the validation of model through workshops with 3 small firms. Based on research methodology adopted, was identified that rigorous cross-case analyses were realized in this domain (Pardo, 2012; Rapitsenyane, 2014).

Outcomes also evidenced a set of several management and design creative tools to perform different tasks supporting SPSS transition process. Before makes correlation between PSS principles, Business Model Canvas (BMC) it was applied to establish value proposition to PSS (Xing and Ness, 2016). After applied several Design Thinking (DT) tools, Orloff and Heinz (2015) summarized that DT workshops enable manufacturing SMEs to explore the potential of PSS as they are fast and inexpensive compared to normal R&D activities. The interactive workshop realized in Rapitsenyane (2014) begins applying PESTEL to external scan and SWOT to scan internal environment identifying SPSS opportunities for SME in existing/new markets. Next, Persona is used to clarify who users are in order to define the market for the new company vision. These process results in a SPSS oriented company vision and potential service idea for a new/existing product. Thus, Mindmaps is used for exploration of concepts to draw inspirations by benchmarking existing in local/external successful SPSS offers. In empower and coordinate stage, Customer Journey Maps and concept prototyping test resulting in promising SPSS solutions. Next, the solutions are filtered in terms of value to stakeholders and resource commitment required with BSC, resulting in a unique value proposition refined for initial user trials.

On other hand, typical management tools are used. For example, Lelah et al. (2014) adopt scenarios visualization for strategic, tactic and operational analysis to support decisional processes towards SPSS. The ADVP framework by Tonelli et al. (2009), adopted benchmarking international with competitors, semi-structured interview with customers, different 'global PSS scenarios' PSS scenarios. In these scenarios, increasing level of services associated to products is verified, and SME evaluate the change of its value/supply chain, outsourcing and partners. Next, risk, cost/profit and business sustainability (i.e. environmental impact equation) are carried. Sustainability indicators, scenarios and interviews with SMEs (Sundin et al., 2015), graphical visualization (Lelah et al., 2012), survey with clients and LCA (Salazar et al., 2015), management templates and exploratory survey with SMEs (Pardo, 2012; Pardo et al., 2013) are others applications.

In short, findings from research techniques and tools supporting transition, shows initially that quantitative approach are still rarely applied. Qualitative research techniques and tools, case study and workshop to validation of artefacts predominate. Also is noted a lack of wide survey methodologies and theory testing works as research techniques. Results from literature permitted suggest approaches and tools that can be adopted at different levels of transition process. Such as, to develop the conceptual design of SPSS offer applying design tools (e.g., BMC, DT, customer survey, mindmaps, customer journey maps and prototyping), to stimulation and management of transition applying management approaches (i.e. scenarios and strategic/tactic/operational analysis) and to assessment (e.g., BSC, risk analysis, cost and profit analysis and sustainability assessment, among others).

Furthermore, there is the comprehension of which assessments strategies contribute to minimize fails in implementation stage, and for this reason it is a fundamental stage. Particularly, sustainability indicators can be applied in different levels/phases towards SPSS and can be considered a critical issue towards a SPSS transition (Kjaer et al., 2016). Anyway, it is possible affirm that LCA and comprehensive sustainability indicators can help this visualization in SMEs context. Lastly, despite of societal analysis be cited in SPSS literature (Mylan, 2015; Ceschin, 2013) as a critical factor, none specific model or framework for societal impact analyses can be found in literature.

5.4.5 Mains Transitions Outcomes and Findings

After explore specific topics such as research techniques, tools and business context, this section discusses the final or partial results obtain with the SPSS transition. Lelah et al. (2014) summarize that scenarios help identify the most important risks during transition. They can be a lever to integrate the concepts of usage and sustainability. Scenarios formulate possible futures and provide a shared vision and can be used to guide and to clarify its vision and make the right decisions to support the transition to SPSS. After proposed a set of key principles to value proposition, Xing and Ness (2016) concluded that clients do not necessarily need to make a big jump to a complete PSS solution, but can take steps progressively and incrementally towards this. They also call attention to the need of include the risks (especially financial risks) and benefits in transition process and to develop a model incorporating a systematic/structured innovation mechanism to enable an integration of product, service and business model designs. In our point of view and based in Design Science Research methodology proposal (March and Smith, 1995) in this case a method is more suited than a model.

Rapitsenyane (2014) found that SMEs engage in collaborations appears to be shaped by their level of trust and comfort with potential partners. The author found that is possible the SPSS transition in SMEs with no prior design knowledge, nonetheless, initial investments in knowledge creation are significant. This challenge is an addition to already existing operational and strategic barriers that SMEs face towards competitive edge. Also, a structured interpretation of factors to address in developing SPSS using sustainable design was obtained: the significance of SMEs drives to inquire about SPSS benefits induce build understanding, making SMEs refer to examples they are used to reflections and familiar experiences. This builds confidence in SMEs to engage empowerment and coordination, given a picture of their organization as SPSS provider. This organizational outlook generates the perception of how SME would create added advantage with SPSS. A framework is proposed to use at early stages of starting to engage with PSS, where more design and sustainable design guidance will be instrumental.

Pardo et al. (2012) investigated how ICT leverage SPSS opportunities in SMEs and affirm that efficient firms with higher innovation capacity, flexible operations and better communications skills are part of the benefits of a SPSS but are also part of the competences required. Results showed lack of connection in strategic terms between the adoption and use of technologies with design and sustainability issues. Also, the lack of financial capacity to projects and lack of sustainable awareness can be overcome if the inclusion of concepts to develop SPSS is done through a third party such as Universities, Consultancies, Government Agencies or any organization with the capacity to support organizational projects in SMEs. This alternative could help to train companies in areas such as sustainability, strategy, design and technologies in a structured way.

In Pardo et al. (2013) the main reasons to SMEs to adopt and use ICTs are related to economic indicators and there is no evidence of a connection between that use of technology and the development of SPSS, even when the majority perceives that connection as positive. For the Colombian SMEs investigated, aspects related to sustainable business practices are not the main focus in their objectives and organizational planning confirming previous literature. However, they have been developing projects related to these aspects and these projects should be used as a starting point for a transformation towards SPSS. Moreover, they concluded that there is a general lack of understanding in the SMEs, about what sustainability means and what the implications are for them to transform their operations toward sustainability. Additionally, the firms apparently did not see the possible advantages of a PSS related to the relationships with other stakeholders except from the relationship with their customers. However, there was no mention of changing how they satisfy their customers.

SMEs need be supported in the assessment/implementation of PSS strategies with the development of specific frameworks and guidelines (Tonelli et al., 2009). The transition requires a strong effort for changing from and old business model into a new one. Internal analysis is needed for assessing and implementing PSS (main areas, critical factors, risks) to be explored, assessed and evaluated (Tonelli et al., 2009). On other hand, the mains results in Salazar et al. (2015) shows that environmental gains can become significant. The author highlighted some factors such as, the need in to think further in terms of functions, user expectation and acceptability and that a good understanding of the functional unit of the PSS considering life cycles can guide the designer.

Orloff and Heinz (2015) results offers interesting insights: i) the initial steps of SPSS transition require commitment of the top management and for continuous innovation in the long-term, a supportive integration of the employees is important; ii) the organizational structures should be flexible and adjusted to the service offer and the person who fills the position; iii) pilot phases and stepwise organic growth are keys to PSS development; iv) a human-centred firm culture supports a deeply embedded user-centeredness. This mindset can be taught to new field personnel, accomplishing the demanding task of distributing PSS, by special trainings; v) long-term PSS contracts and CRM tools turn SMEs into premium customers of high interest while the utilization rate has to be balanced.

According to Sundin et al. (2015) there are two main reasons why SMEs move to PSS: economic motivation to meet customer demand and strong belief in PSS helping SME to become more sustainable. SMEs focused in customer value are more focused on customer satisfaction and economic benefit. While SMEs focused in sustainability, are focused in environmental indicators. They also concluded that the sustainability work and PSS progress awareness mostly depend on size, personal interest and maturity of SME. SMEs must develop objectives using some of selected indicators and establish scenarios to make them possible. In this same direction, Lelah et al. (2012, p. 312) conclude that “[...] a more systematic, comprehensive method for assessing sustainability issues should be developed in order to fully utilise the potential of the proposed PSS.” Regarding the need of partners/network to leverage SPSS successful, they suggest that SMEs collaborating together have the potential to build and run large, complex and dynamic systems.

Ragarding integration of ICT and design approaches to SPSS transition, Pardo (2012) synthetize that this is a new alternative to designing SPSS, in order to contribute by several ways. First, outlining the area of exploration to diagnose/evaluate the capabilities of SME to design and eventually develop SPSS in terms of design practices, use of ICT, and awareness of sustainability. Second, defining areas of opportunity to SPSS. Third, reorienting the business strategy of an organisation, turning its attention towards the role that design and ICT can play as creators of value. Lastly, the SMEs involved in the research showed a positive attitude to moving towards different business models with the expectation of achieving better performance, more clients and sales.

In sum, results demonstrated the some critical factors to be addressed by manufacturing SMEs. First, there is the understanding of which internal/external risks analysis (i.e. financial risks) are critical aspects and scenarios help identify the most important risks (Sundin et al., 2015). Second, SMEs must develop objectives using selected indicators to support the transition process. Third, systematic and structured SPSS methodologies enable successful transition (Xing and Ness, 2016; Tonelli et al., 2009). Fourth, the lack of sustainable awareness, mainly in a SPSS life cycle point of view, can be minimized with the clarification of it benefits of servitization. Lastly, there is in the literature the comprehension that partners/network are a critical successful factor to SMEs.

5.4.6 Barriers towards SPSS in manufacturing SMEs

Besides, considering specifically intrinsic characteristics of SMEs, the transition towards SPSS can be still more difficult. Several barriers from experienced transition are highlighted in literature. Rapitsenyane (2014) summarized as mains constraints: the lack of finance and poor market performance of products contributing to enormous low profit margins, the low engagement in innovation activities, low design awareness and follower mentality, lack of clear business strategy, negative experiences from tried/failed collaborations cause scepticism to new projects, and the understanding of sustainability is still limited to economic sustainability, turning environmental and social gains low priorities for SMEs.

Pardo (2012) found similar barriers, such as the limited knowledge and awareness in social and environmental, lack of knowledge/awareness of sustainability, and lack of a business strategy. Barriers related to organisational weaknesses also obscure the possibility to design and implement SPSS. Clear barriers that blocked of SPSS transition are the misunderstanding of the PSS concept, undervalued and unclear design practices, disarticulated use of ICT and a worrying lack of trust and collaboration in the supply chain. The assumption that giving SMEs access to ICT will make them more competitive is only partially true. Because, if the SMEs are not able to integrate the technologies with their main production processes, and if they do not have a business strategy where technology can play a role, similar problems will be repeated.

Orloff and Heinz (2015) identified as barrier, the management commitment in initial implementation of SPSS, internal conflicts between sales and service, recognition of market demands, problems to pricing services, difficult to balance the overall performance with social/ecological issues and problems with low value products. They reinforce that this difficulties also can become success factors if were perfected. They found that the success in sales mainly depends on the communication of the leasing-contract to convince customers by savings. Potential internal conflicts between sales and service and shift to service mindset are solved putting customer satisfaction in the center of attention, problem of pricing services are solved through a clear cost structure. The stronger market competition and lack of market demand is minimized with benchmarking on a national level with competitors and on SME level and have a bigger sales team.

Pardo et al. (2013) found similar barriers and added new factors, such as lack of understanding in the SMEs about what sustainability means and what the implications are for them to transform their operations towards sustainability, lack of formal business strategies with a design process suggests that work is needed on this area before thinking about developing SPSS. They also highlighted the organizational resistance, large investments required, complexity, balance between sustainable business principles, public acceptance, financial uncertainty, absence of demand, difficult relationships between stakeholders. Furthermore, there are barriers related with ICT waste or non-use, obsolescence of products, unknown effect of ICT, equipment and application, rebound effects, lack of knowledge, large investments required, rematerialization. It is not yet clear how academia, policy makers, non-governmental organizations and the public these actors can work together, how the support should be given, and what mechanisms should be used to develop PSS in SMEs (Pardo et al., 2013).

The sustainable infusion and awareness depends on the size and, resources such as time, specialized, personal interest of employees and maturity or time working in sustainable issues of SME (Sundin et al., 2015). There is a lack of understanding about the changes required to their current business models and in how these changes may be undertaken in a progressive manner and measure the impacts on the transition (Xing and Ness, 2016).

Problems regarding the need of change management in the business also are explored by literature. The mains challenges to Lelah et al. (2014) are moving the business model based on transactions to a model based on relationships, require global planning and changes in management practices and rethink business models replacing value of exchange by value in use, involving long term relations. Lack of managerial competences and resources to manage such change and implement PSS strategies (Tonelli et al., 2009). Lelah et al. (2012) highlights difficulty in changing mindsets from product ownership to use, share responsibility for system performance between provider and the user, ant the lack of tools linking the micro-system of the company and its process of development of products/services to the sustainability expectations of society.

Pardo et al. (2012) found a complex situation with internal and external actors involved in SMEs investigated, lack of connection in strategic terms between the adoption and use of ICT with the other areas (i.e. design and sustainability). The obstacles (short term management, tight financial budgets etc) can be overcome if the inclusion of concepts to develop SPSS is done through a third party such as Universities, Consultancies, Government Agencies or any organization with the capacity to support organizational projects in SMEs. The general lack of awareness about what a sustainable operation is in SME is reflected in few actions taken by the SMEs in the environmental/social domain. From these obstacles of literature, an integrated classification of barriers can be summarized as following.

Table 5: Main barriers towards SPSS in manufacturing SMEs

Code	Category	Barriers
B-FI1 B-FI2	**Financial**	Lack of financial resources. Financial vulnerability.
B-MK1 B-MK2	**Market**	Poor market performance of products. Difficulty in recognition of market demands.
B-BH1 B-BH2 B-BH3	**Behaviour**	Low engagement in innovation activities Follower mentality. Mental models.
B-CM1 B-CM2 B-CM3 B-CM4 B-CM5	**Competences**	Lack of sustainability and design awareness. Lack of managerial competences. Lack of design competences. Lack of sustainability competences. Knowledge gaps.
B-MT1	**Motivation**	Past negative experiences in project, cause scepticism to new initiatives.
B-SU1 B-SU2 B-SU3 B-SU4 B-SU5	**Sustainability (T BL)**	Sustainability awareness limited to economic perspective. Limited knowledge and awareness in social and environmental issues. Lack of understanding about what the implications toward sustainability transition. Difficulty to balance the overall performance with social and ecological issues. Products with low value are obstacle to sustainability performance.
B-ST1 B-ST2	**Strategic**	Lack of business strategy. Difficult balancing sustainable business principles.
B-OR1	**Organizational**	Organisational weaknesses and change resistance.

B-OR2 B-OR3 B-OR4 B-OR5 B-OR6		Organizational culture. Conflicts between sales and service. Low diffusion and waste in ICT. Short term management. Need of replace value of exchange by value in use involving long term relations.
B-SP1 B-SP2 B-SP3 B-SP4 B-SP5	**SPSS process**	Lack of understanding of SPSS concept. Complexity of PSS. Need of large investments. Lack of understanding of the changes required. Lack of tools linking the company' micro-system and its process of PSS development to the sustainability expectations of society.
B-MT1 B-MT2	**Methods and tools**	Lack of frameworks, models or method guiding the transition. Lack of comprehensive method for assessing SPSS sustainability
B-SC1	**Supply Chain and Network**	Lack of trust and collaboration in the supply chain.
B-HR1 B-HR2	**Human Resources**	Lack of social competencies to leading positions. Lack of a SPSS leader/champion pulling the transition.
B-PR1	**Products**	Low value products resulting in low profit margins.
B-LE1	**Leadership**	Low management commitment in initial implementation of SPSS.
B-ST1 B-ST2	**Stakeholders**	Difficult relationships between stakeholders affecting SME. Changing mindsets from product ownership to use.
B-OE1	**Orchestrated Ecosystem**	Lack of an organized ecosystem (i.e. academia, policy makers, governmental organizations, public) supporting SPSS transition.
B-CU1 B-CU2 B-CU3	**Customer**	Public or user acceptance. Need of replace value of exchange by value in use involving long term relations. Share responsibility between provider and the user.

Despite the related barriers not be an exhaustive list, they represent the most part of significant difficulties faced by SMEs. On the one hand, these findings reveal some expected internal barriers associates with intrinsic characteristics of SMEs as a whole, but that become still more sensitive, in the case of SPSS transition. Such for example, the lack of financial resources, financial vulnerability and short term management can turn still more difficult the engagement in innovations activities of a SPSS project. The lack of competences (i.e. in high management, employees, knowledge on PSS) turns more difficult to SME establishes a clear vision of sustainability based on Triple Bottom Line. The lack of business strategy, formalized process sums up to lack of models/method guiding the transition and the absence of an orchestrated ecosystem increase the unsuccessful risks to SME.

On the other hand, there are barriers directly related with the nature and novelty of PSS and SPSS business models that require new attitudes to be adopted by company. For instance, change mindsets from product ownership to use, replace value of exchange by value in use involving long term relations, design/sustainability competences and a general misunderstanding of the changes required. Barriers related with poor market performance of products and difficulty in recognition of market demands, occurs mainly due social reasons and the difficult to change existing customers' habits (Ceschin 2013).

In a nutshell, is possible suggests that to some extent this context does not mean that the development of SPSS in SMEs will be an activity thoroughly difficult. Indubitably, the constraints are more critical than the large companies faced. However, some lessons learned from empirical studies can mitigate this process, scaling-up a successful transition. Next section discusses the mains lessons learned.

5.4.7 Lessons learned and guidelines towards SPSS transition

The organization of knowledge accumulates transition studies and the on lessons learned resulting in select studies on SPSS may help to mitigate the negative effect of several barriers faced by SMEs. Thus, this section explores this perspective. According to Lelah et al. (2014), before moving towards SPSS, first the SME must clearly formulate the problem it faces. Also, often starting with a small part of the business and then extending to the whole organization is the best alternative, to further cover the whole business structure, including relationships within the value network, organizational culture and mental models.

As Xing and Ness (2016) affirm, careful design of business cases is required to increase resource efficiency, while even more consideration is necessary to increase social sustainability via affordability and generating increased employment. Key principles must be considered to obtain a successful SPSS offer. For instance, the product, should have relatively high market value or relatively high selling prices in comparison with other similar products, durable/long physical life, designed with minimal footprint and with modular structure. Regarding the service offer, is expected that the ownership of product be retained by service provider and must be some basic options (e.g. leasing or renting, desktop support, performance monitoring and maintenance contract, take-back system) and their modular combinations building PSS. The service should contribute to increase environmental values of ownership and reduce total cost of ownership. In a management perspective, should exist a champion in the client company and the adoption of change management principles (e.g. commitment through conveying the value of PSS across the client) are good strategies.

On business model, Xing and Ness (2016) suggest as key principles, define who customers are, the customer values, define the processes (both internal and external) to engage and interact with customers, what resources and assets to possess and utilise, what and how revenue can be generated and associated cost implications. Also the offer needs to be market-oriented and customer-focused and able to address a particular customer value network and to fulfil functional, economic, environmental and social demands. Regarding employees, should undertake training in new skills associated with PSS, reward systems, monitor/report the PSS performance in meeting service requirements and measure/control environmental and economic performance in different scenarios.

Tonelli et al. (2009) define as important guidelines make risk, cost, profit and business sustainability analysis, in order to economically, financially and environmentally characterize the possible SPSS strategies to SME. As well as, develop a marketing plan to promote the new business model in the market, both versus existing and new customers. Specific support for its transformation based on frameworks and guidelines for managing PSS proposals also is recommended. Lastly, it is important verify availability of human resources, Infrastructure and ICT competences in SME. Similarly, Lelah et al. (2012) say that SMEs must be supported from an ICT backbone facilitating communication of data within the network. A detailed description and role of the user and his activities during value creation must be done. Others key factor are the co-creation of value by user and provide a basis for exploring possibilities across the supply chain network.

Regarding sustainability assessment, Sundin et al. (2015) suggests as guidelines that sustainability indicators should be adjusted to each SME' needs according sector activity, the number of indicators need be limited much as possible to minimize extra work and that the PSS offer and indicators need be developed in cooperation with currents and future customers. They also stated that customer satisfaction is an important economic indicator.

In Orloff and Heinz (2015) study, first, from customer perspective is noted that, (i) capturing user needs fosters empathy with the customer's processes; (ii) a user-centered firm culture paired with high top management is a key for long-term PSS success; (iii) understanding that create value are competences on customers' processes; (iv) exist the routine of personal contact between employees and customers, and (v) Close relations along the value chain to both designers and customers. Key factors related to SPSS offer also included: customization, existence of portfolio management, sustainability orientation, engaging in networks, the presence of a catalyst leader, internal competencies regarding products/services and short communication routes for fast decision-making and flexibility in strategic decision-making. Regarding to sequence, is suggested first design the service aspect and then matching the corresponding product part of the PSS as especially beneficial for sustainable outcomes due to the high dematerialization potential.

Key factors associated with continuous innovation of SPSS are: the existence of a clear cost structure for long-term planning, investments for products and production, company's rooted identity in regional structures, continuous innovation behaviour, supportive integration of the employees is important for continuous innovation in the long-term. Workshops (i.e. Design Thinking) enable manufacturing SMEs to explore the potential of PSS as they are fast and inexpensive compared to normal R&D activities (Orloff and Heinz, 2015). Pardo (2012) recommended external support such training and financial support is an important element in the positive perception and disposal of SMEs to SPSS.

Outcomes in Pardo et al. (2012) suggest as lesson learned, integrate design activities, for example SPSS design and ICT, to virtualization, production, evaluation of prototype, to recovery, repair and resale of products, to develop a collaborative platform between SMEs. Besides, use ICT to the optimization of the production, improving the decision making.

Rapitsenyane (2014) also defined key principles moving towards transition, emphasizing the design activities. First, the involvement of designers through a strategic design approach give benefits demonstrating differentiation through services in manufacturing SMEs. This can incrementally expose SMEs to SPSS and its benefits since they mostly perceived it as a worthwhile route. Second, the flexibility of designers working styles and their adaptability to different situations, especially to use design capabilities in non-design led product-oriented SMEs, can promote radical innovations concepts like SPSS. Third, key design leadership capabilities should be developed throughout the process, are crucial and effective in engaging SMEs in design of SPSS. Fourth, creating design awareness in SMEs, would not only contribute to the building differentiation potential, but also build other related capabilities, as in sustainability. Thus, design capabilities can be developed sustainable design capabilities. In short, design capabilities (i.e. identify user needs) can make a significant contribution in mind-set change of SMEs towards servitization.

Pardo et al. (2013) suggest as guideline use ongoing projects as a starting point for a transformation toward SPSS. It confirms a limited understanding of the PSS concept and areas suitable to be filled with a more complete presentation of the implications, benefits, main features and opportunities of a SPSS business model.

Rapitsenyane (2014) also highlighted key factors on SME' engagement. The engagement in innovation activities and use of technology can reduce the complacency with small gains and the follower mentality of SMEs. Still, for SMEs to embrace environmental and social SPSS sustainability pillars, it is important that interventions clearly demonstrate environmental and social practices with financial gains. The use of a systems success factors broad list, addressing suggestions for common problems like a check list, places the availability of designers with sustainable design capabilities at the centre of its implementation and reduces of chances for failure of intervention.

Generally there is low user involvement in SMEs' product development approaches contributing to poor sales, however, the user-centred design approaches could close this gap (Rapitsenyane, 2014). According to Salazar et al. (2015), the key factor to success is the understanding of customer' needs in order to maintain long and short term satisfaction. All the same, a balance must be found between the satisfaction of needs and environmental aspects. To make this, products and services with different functional units representing the same level of service for users have to be compared. In the same way, the collaborative external arrangement, trough partnership with other SMEs, experts, entities and so on can be seen as success factor (Rapitsenyane, 2014). In summary, the lessons learned were classified into categories as following (Table 6). They are useful to understanding the micro-foundation for successful SPSS business model implementation in several related categories.

Table 6 : Lesson learned/guidelines supporting transition

Code	Category	Lesson learned/guidelines
L-SP1	**SPSS Process**	Clearly formulate the problem and share the scenario before moving towards
L-SP2		SPSS.
L-SP3		Realize the SPSS transition in gradual form over time.
L-SP4		Develop a detailed design of offer based in sustainability, considering actors, stakeholders, channel and so on.
L-SP5		Established external partnership (large companies, suppliers, entities,
L-SP6		governmental, universities, SME partners, consulting) to develop a robust value proposition to customer.
		Define the type of PSS suited to customer needs.
L-SP7		

L-SP8		Develop the service offer based on customization, modularity and in portfolio options (i.e. leasing or renting, desktop support, performance monitoring and maintenance contract, take-back system). Explore design capabilities to create radical innovations concepts in offer. Adopt structured guidelines and frameworks for managing SPSS proposals.
L-P1 L-P2 L-P3	**Product**	Choice a product with relatively high market value or high selling prices in comparison with similar products. Develop a new or choice a existent product with long physical life cycle, minimal footprint and modular structure. Involve products' target customers and users in product development.
L-S1 L-S2 L-S3 L-S4 L-S5	**Sustainability (T BL)**	The value proposition based in sustainable-oriented service contributes to increase environmental values of ownership. Carried out sustainable-oriented risk analysis. Develop sustainability indicators in cooperation with currents and future customers and suited to SME' needs according sector activity. Implement actions to increase the design awareness (i.e. training, consulting, partnership). The value proposition should clearly demonstrate financial gains in environmental and social practices.
L-CU1 L-CU2 L-CU3 L-CU4 L-CU5	**Customer**	Define the PSS champion in the client company to facilitate the communication and results. Precisely define the target customers, needs and their values. Establish channels and internal/external business process to engage and communicate with customers based on co-creation of value. Define business indicators in partnership with target customers. The top management should implement actions and process to diffusion of user-centred culture.
L-M1 L-M2 L-M3	**Marketing**	Develop a value proposition offer market-oriented and customer-focused fulfilment functional and sustainability needs. Develop marketing plan to promote the offer. Realize national and international PSS and SPSS benchmarking.
L-O1 L-O2 L-O3 L-O4	**Organizational**	Apply change management principles based on value proposition within company. Implement business process to continually monitor sustainability performance of offer (routine of personal contact between employees and customers, meeting service etc). Implement fast and flexible process (i.e. fluid communication) in strategic decision-making. Implement a clear cost structure for long-term planning and pricing service.
L-HR1 L-HR2	**Human Resources**	Implement reward systems and integration of the employees. Search external support need regarding training.
L-C1 L-C2 L-C3	**Competences**	Developed internal capabilities in design activities. Established external partnership (entities, governmental, universities, SME, consultant) to close gap in competences. Realize training in new skills associated specifically with SPSS offer.
L-F1 L-F2	**Financial**	Carried out risk, cost, and profit analysis. Identify external financial support and develop a financial offer mapping available.
L-I1 L-I1	**ICT activities**	Implement ICT support to facilitating the PSS network communication and decision making. Use ICT along the life cycle of SPSS (i.e. design, virtualization, production, evaluation, recovery, repair/resale, collaborative platform).
L-SC1 L-SC2	**Supply Chain and Network**	Use ICT support exploring possibilities across the supply chain network. Adopt proactive behaviour aiming collaborative partnership in supply chain network with others SMEs, entities, large companies, experts and so on.
L-L1	**Leadership**	Choose a catalyst leader to pull the transition process.
L-B1	**Behaviour**	Continuous innovation behaviour in business processes user-centred and value proposition-oriented.
L-MT1 L-MT1	**Methods and Tools**	Implement flexible and hand on workshops (i.e. Design Thinking, Canvas) evolving customers to develop innovative value proposition in SPSS offer. Use a systems success factors guideline addressing suggestions for faced problems along the transition.
L-M1	**Motivation**	Analyse SPSS cases in SMEs from governmental funded projects or literature

From an analysis of guidelines cited in literature, a new category on ICT emerged. On the whole, an extensive list was organized. Even though some items could be classified into other categories, this guidelines list can be systematically used to found pathways in making decision process or to solving problems faced in planning/developing stage, during the transition process. The set of guidelines contemplate the Beginning, Middle and End of Life of SPSS life cycle of SPSS. A complementary correlation analysis was performed between barriers and lesson learned and is presented in next section.

5.4.7.1 SPSS Decision Matrix

From a detailed analysis of literature results regarding barriers or problems and lesson learned presents in guidelines format, complementary correlations between them could be identified. Cook (2014) affirms that useful research is need in various PSS contexts associating design processes to illustrate the diversity of approaches which may be built upon and extended. Results from case studies research are useful for fully towards the strengthening of generalisable theory of PSS. In this sense, the proposed matrix follow the Cook' proposition, being developed from results of case studies in SPSS transition. Thus, a matrix supporting the decision making process by SMEs during the transition process to SPSS was developed (Fig. 3).

The matrix can be interpreted in following manner: considering a barrier or problem faced by SME in any stage of SPSS transition process, and then selected (axis ‘x’), the correspondent guideline(s) (axis ‘y’), if applied, could result the following positive impact levels: null/very weak (in blank), weak (+), medium (++), strong (+++). Hence, designers, academics and PSS providers can use the matrix basically by three different ways. First, considering the specific context of a SME in analysis and their problem(s) or barriers(s) faced that need be overcome. This first way to use the matrix can be done selecting the correspondent guideline(s) matched as strong impact (+++). It means if the SME faced the barrier (s) “x” than the guideline(s) to overcome these barriers are the following “y”. For example, if one barrier is the poor market performance of SME' products, some correspondent suggested guidelines found are: to develop a value proposition offer market-oriented and customer-focused fulfilment functional and sustainability needs and a marketing plan to promote the offer. Others guidelines (+++) also can be identified by analysis of matrix' rows. Hence, this first way to use result in a set of possible suggested guidelines or actions to support the make decision process in SMEs aiming solve the current problems/barriers. This can be defined as the more conventional way to use the matrix.

Besides, a second possible use to matrix is realizing the analyses of past making decision taking by managers in SME. This can be done comparing the action being analysed by SME to a specific problem/barrier in the past, with the suggested guidelines matched as strong impact (+++). In this second way use, the SME can verify if took the correct decisions in past and eventually found news suggested actions/guidelines to solve effectively past problems that still is affecting their performance in the present.

The third form to use the matrix is based on proactive behaviour of SME. In this case the matrix could be used from right to left side. If, for example, the SME recognize internally positive factors and tactics adopted in which perform very well over time, it is possible to explore this 'force' to gain more competitive advantage in the market. To make this, after identify this 'force', a correspondent identic or equivalent factor guideline must be identified in columns. Hence, the SME can explore this "force" in order to minimize a specific barrier existent or even a set of them, as co-relation matched. If for example, the correspondent problem/barrier doesn't exist within SME, the firm can preventively defend from this possible occurrence. For instance, if the SME is recognized by have accumulated internal capabilities in design activities, thus exploring more this positive aspect could minimize or in some time blocked the appearing of problems such as the low market performance of products, low sustainability/design awareness, lack in recognition market demands and others.

Fig. 3: SPSS Decision Matrix

Guidelines

Problems	L-F1	L-F2	L-M1	L-M2	L-M3	L-B1	L-C1	L-C2	L-C3	L-S1	L-S2	L-S3	L-S4	L-S5	L-O1	L-O2	L-O3	L-O4	L-HR1	L-HR2	L-M1	L-SP1
B-FI1	+	+++	+			+		++														
B-FI2	+++	+	+					++										++				
B-MK1	+	+	+++	+++	++	++	+++	++		+	++	++		+++		+						+
B-MK2		+	+++	+++	+	++	+++	++		+	++	++				++						++
B-BH1		++	++			+++	++	+	+					+++	+++		+		+++	++	+	
B-BH2	+	++	+++		+	++	+++	+						+	+	+	+		++	+	+	
B-BH3	+	+	+++		+			+							+++				++	+		
B-CM1		+	+++			+	+++	++	+++	+++	+	++	+			++				+++	+	
B-CM2		+	+			+	+	+++	+++	+			+							+++		
B-CM3		+	++		++	+	+++	++	+++	+++			+++							+++	+	
B-CM4		+	+++		++	+	+++	++	+++	+++			+++			++				+++	+	
B-CM5		+	++		++	+	+	+++	+++	+			+		+			+		+++		
B-MT1			+	+		++								++	++							
B-SU1			++		+		+	+		++	++	++	+	+++		++						
B-SU2			++		++	+	+	++	+	++	+++	+++		+++		++				+++	++	
B-SU3			++			+	++	+++	+	+++	+++	+	++	+++		++					++	
B-SU4		+	++	++		+	+++	+	+	+++	+++	+		+++		+					+	
B-SU5	+++	++	+++		+	++	+++			+++		++	+	++		++						
B-ST1	+	+	+++	+	+	++		+							+		++	++			+	
B-ST2	+		+++			+	+			++	+							++			+	
B-OR1	+	++	+		++	+++								++	+++		++		++			
B-OR2	+++		++			+++	++								+++		+		+			
B-OR3	++		+++	+		++	++			+							+++	+++	+			
B-OR4						+																
B-OR5	++	+++	+++	++		+++									+		+	+				
B-OR6						+	+	++							+							
B-SP1			++		+++	+	++	++	+++		++	+	+++	++				++		+++	++	++
B-SP2			+++	+	++		+++	++	++	+	+	++	+									++
B-SP3	+++		++	+	+		+	+++														
B-SP4			+++		+++	++	+	++		+			+++		+++			+				+++
B-SP5					+		+			+	+++	+++	++	++		++		++				
B-MT1							+++				+		++	+								
B-MT2			+				++				+++	+++	+	++						+		
B-SC1						++		+++														
B-HR1																	++					
B-HR2																	++		+			
B-PR1			+++	+++	+++	+++	++						+					++				
B-LE1					++			+							+++				+	++		
B-ST1			++	+++	+			++									+++					
B-ST2			+++			+	+										+					
B-OE1								+++									+					
B-CU1	++	+	+++	+++	+++	+	++			++			++	+		+++						
B-CU2	+		+++	++	+		+			+						++						
B-CU3			+++	++			+				+			+								

Problems	L-SP2	L-SP3	L-SP4	L-SP5	L-SP6	L-SP7	L-SP8	L-CU1	L-CU2	L-CU3	L-CU4	L-CU5	L-SC1	L-SC2	L-P1	L-P2	L-P3	L-L1	L-I1	L-I2	L-MT1	L-MT2
B-FI1	+++		+++		+++									++	++							
B-FI2	+++		++		++									++	+++							
B-MK1	+	+++	++		+++	+++			+++	+	+++	++		+++	+	+++	+++		++	+++	+++	+++
B-MK2	++	+++	++			+++	+++		+++	+++	++	+++		+++		++	+++			+++	+++	++
B-BH1	+++					++	+++							+++				+++		++	+++	++
B-BH2	+		++			++	+			+		++		+++				++			+	
B-BH3						+	+			+		+		++				+			++	
B-CM1	+++	++	+			+++	++							++			++				++	++
B-CM2	+++		+				++							+			++			++	++	++
B-CM3	+++		+++			+++	++										++			+++	+++	+++
B-CM4	+++		+++			+++	++							+			++			++	++	+++
B-CM5	+++		+++			++	++						++	++			++			+++	++	++
B-MT1	+	++	+		++					++		++		++								
B-SU1	++		+			+++	+					+				+++						
B-SU2	++			++			+					+++	++						++			++
B-SU3	+++		+++			++	++				+++	++		+++		+++			++			
B-SU4	++			++	+++	+	+++				+++	+++	+	++		++	++					++
B-SU5	+++				+++	+++	++		+		+++	+++		+++		+++					++	
B-ST1	+	+++	++	+++	++		+					+++		+							+	
B-ST2	+	++	++	++	+	++	++				++	+		+							++	
B-OR1	+++		+++	+++		++	++	++	+	+++				+++					++		+++	
B-OR2	++		+																		++	
B-OR3		+	++		+			+++		++	++	+++			+	+		+	++		+	
B-OR4				+				+++		++			+++	+					+++	+++		
B-OR5	+												++									
B-OR6					++	++		+++	+++	+++	+		+++									
B-SP1	+++	+++	+++	+++		+++	+++			+				+++	+++	+++	++	+++		+++	+++	+++
B-SP2	+++	+	+			++	+++							+++		++	++	++		+++	+++	+++
B-SP3	+++		+++											+++		+++	+					
B-SP4	+++	+++	+++	+++		+++	+++	+++	+++	+++				+++				++	+++	+++	+++	++
B-SP5	++			+++		++	+++						+				+		+	+	+++	++
B-MT1	++		+		++	++											+			++	+++	+++
B-MT2	+				++	++	+++		++										+	+	++	+++
B-SC1	++			++									+++	+++						+++		
B-HR1	+																					
B-HR2	+		+++					+	++													
B-PR1	+		+++		+++	++	++				++	+++		+++	+++	++	+++					
B-LE1	++		+											++			+++	+++		+++		++
B-ST1	++	+++	+++	+++				+++	+++			+++		+++			+++	+++	+++			
B-ST2	+++	+	+	+++				+++	+++		+++			++			+++				+	
B-OE1			+++				+															
B-CU1	+	+++	+++	+++	+++	+++		+++	+++	+++	+++			+++	++	+++	+++		++	++	+++	
B-CU2	++		+	+		++		+++	++						++		+++					
B-CU3	++	++		+++		++			+++	+++		+++	+	+	+	++	+++		+++	+++	+	

Vezzolli et al. (2015, p. 10) stated that “[…] further research is needed to better understand the SPSS introduction and diffusion process (and its critical factors) and how it can be designed, managed and oriented”. In short, the matrix is a systematic and structured tool supported from literature results and insights, guiding internally the SMEs managers to take best decisions over time in any stage of their SPSS transition process. It can be considered an innovative methodological proposition for competitiveness. It supports SPSS design capacity for SMEs by offering pathways that address fundamental competitiveness concerns of SMEs. A criterion suggested to be adopted in the choice of guidelines to the three ways to use the matrix is the prioritization of guidelines that have strong impact (+++) affecting at same time as many barriers as possible.

Especially in SMEs, characterized by gaps of knowledge, the matrix can be useful assisting the decision making process. Individually, these guidelines can also be classified as short, medium and long term actions. Therefore, we suggest make the choice mixing these time criteria. The matrix can be complemented by PSS community aiming turning more robust and effective use by companies. Also, customized versions to traditional PSS or contingent cases (segment of business, type of PSS, etc) can be developed from this first proposal as baseline. Include quantitative criteria taking as bottom line the co-relations of matrix, is also a possible further development.

5.4.8 Drivers and Benefits

Drivers can be considered as the motivations underlying the decision of developing/implementing a PSS (Annarelli et al., 2016). Despite of transformation in manufacturing SMEs involve several barriers, the drivers moving towards a more sustainable-servictized company result in several competitive benefits. Xing e Ness (2016) noted that the drivers to servitizition were mainly to strengthen competitiveness and differentiation in an increasingly competitive market, the highly price-oriented and commoditised market, make up the shrinking sales in the manufacturing sector creating market opportunities and improve the communication and engagement with customers. Sundin et al. (2015) highlighted mainly drivers related with economic motivation, meet customer demand and sustainability. Regarding to sustainability, the driver is based in a strong belief in PSS helping to become more sustainable and this normally occur when companies already are working to becoming more sustainable and they have found that PSS could be a mean to help them accomplish that. Already the customer demand, is first reason has to do customers not wanting own the product, but rather get the value that the product can produce and without problems such as maintenance and repair.

The economic motivation also was found in others studies. This is linked with expectation of achieving better performance, more clients and sales (Pardo, 2012) and the desire to push for more sales (Rapitsenyane, 2014). Pardo (2012) also found that some of the motivations for using ICT could be used as driver to induce a transformation towards SPSS. For example, the possibility of opening new markets, improving relationships with clients and increasing competitiveness were recognized by SMEs and they are part of the benefits that a SPSS can offer a company. SMEs that recognized these aspects make a potential transformation more likely.

Drivers related with business dynamic and marketing also are highlights. Lelah et al. (2014) affirm that the reasons towards SPSS are related with the need in rethink business models and replace value of exchange by value in use, involving long term relations and understand value creation needs in the market potentially interested by the offer. Tonelli et al. (2009) found the need of improve the product flexibility and logistic services and anticipating market trends and Salazar et al. (2015) was attending customer' needs. An interesting aspect in Salazar et al. (2015) research is that, the choice of PSS as the starting point for industrial offerings was initially based on understanding the customers' difficulty to cope with large amounts of information produced by the sensors that the analysed SME supply. This factor remits to several possibilities of applications of industrial trending topics such as Big Data, IoT and the Industry 4.0 in SMEs context (see Valencia et al., 2015). Similar driver is identified in Orllof and Heinz (2015), in which the SME provides a logical reaction to market pressure and successfully introduced by simply focusing on customer demand.

Despite of barriers faced by manufacturing SME towards a service-oriented and customer-oriented enterprise, several benefits and advantages also are expected in attend their drivers. For example, in the SMEs analysed in Pardo et al. (2013), the main advantage identified was the possibility to enrich their offers with associated services. They believed new services could help them to gain competitiveness, loyalty from customers, and increased sales, aspects that are all part of PSS drivers and benefits identified in the literature. Furthermore, the restricted dimension of SMEs and their dynamism, allow them to manage changes and develop responsibly PSS strategies with customized products-services (Tonelli et al., 2009).

Sundin et al. (2015) corroborated pointed that SPSS helping SME become more sustainable, provide more regular customers and give to SME better control of its products. In order to measure these expected advantages, they suggests that customer satisfaction is an important economic indicator and on the environmental indicator, it could depend of kind of business. On customer satisfaction, Sallazar et al. (2015) affirm that it is a dynamic parameter and market demands can change very quickly. Furthermore, it is notable that SMEs with small and flexible structures are generally well-adapted for converting new ideas into marketable services to be deployed rapidly in changing markets (Lelah et al., 2011; Sallazar et al., 2015).

Rapitsenyane (2014) concluded that design can be used as a strategy through its capabilities to promote a culture of radical innovation in SMEs and adoption of sustainability, resulting in flexibility relate to the technical language of innovation and non-technical language of business. On the benefits in adopt frameworks is allow exploration and definition of competitive SPSS leading to design and development of PSS offerings.

On the whole results shows that remains the economic drivers guiding SMEs to adopt SPSS interventions. Due the constraints related to lack of financial resources and general financial vulnerability seems reasonable have this motivation rather than prioritize environmental or social related demands. Nevertheless, this motivation might not be the main driver in internationalized manufacturing SMEs. In this case, the legal environmental issues, the pressure for focusing on rigorous customer demand and offers based in radical innovations aiming a differentiate position in the market may be more latent. Furthermore, several and multifaceted factors and circumstances involving a successful transition and the attending of expected benefits.

However, based on previous results, critical paths can be designed to small business. First, a start point going to this direction pass by precisely mapping the internal weaknesses and forces, in order to mobilize necessary resources. Complementary, internal analysis also can be extended with the help of our proposed SPSS Decision Matrix. Besides, engaging in networks is very helpful by allowing each other to mutually learning from each other at SPSS introduction and further developments towards servitization (Clegg et al., 2017; McCormick et al., 2016; Orloff and Heinz, 2015).

5.4.9 Research challenges

Several challenges and topics to be explored further are raised by analysed literature. In order to collect these opportunities, when indicate, insights extracted mainly from section of conclusions and discussion of studies was consolidated. Lelah et al. (2014) suggested as research agenda that scenarios can combine sustainable considerations and integrate specific PSS issues like business model, product, service and user life-cycles. Future work should test the full methodology and strengthen the approach particularly for sustainable issues SMEs and also in in large companies. They also affirm that the final scenarios could be made in the form of graphs or a table. Stories in a short film, paperboard or slide display are also commonly used. These later may be used to address a larger heteroclite public or multidisciplinary teams that use different languages with different points of view. Thus, different forms of the final scenarios are possible.

Sundin et al. (2015) advocates the need of SME develop objectives using some selected indicators and establish scenarios to make them possible. To support this process, a framework might be developing. Pardo et al. (2012) highlights that the lack of consistency between the adoption of technologies and other areas and processes in the organization is a big concern that has to be taken into account in a further research as part of the risk assessment of the servitization process. Develop general structure framework is needed in order to use that logic in other SMEs context.

To Orloff and Heinz (2015) further researches on SPSS in SMEs context could establish connections can be drawn to circular economy domain. Also is indicated the application of the proposed framework to examine cases in other industrial fields in order to develop the conceptual tools and necessary software were indicated. The validation in others contexts also is advocated in Salazar et al. (2015), that suggested more studies to pursue the social aspects concerned by degradation of technical performance to reduce environmental impacts. Further research suggested in Pardo et al. (2013) is investigated mechanisms to determine on an individual basis when SPSS, the integration of ICTs and the design process are suitable concepts for SMEs.

For Xing and Ness (2016) a structured model is still necessary to provide a framework to have the TBL dimensions more integrated and a methodical process for their implementation. Research opportunities also exist to include the risks (especially financial risks) and benefits associated with taking each step along the transition stages. change path, so that a company may more confidently transition towards PSS. Is suggested that this new model should also incorporate a systematic innovation mechanism to enable an integration of product, service, and business model designs. Pardo (2012) suggest use the transition model with a SME to design and implement with an external facilitator. The automation of the framework as a business tool also is a considered alternative. The observation of the process of design and development of SPSS in industry is a valuable source of information and insights to reflect and improve transition model proposals.

According Rapitsenyane (2014) it is a key factor to develop design leadership capabilities deployed with a deliberate intention to explore PSS opportunities early. Because, this will encourage a product ownerless culture among consumers, leading to a more dematerialised society and uprooting of more sustainable consumption patterns in the case of sustainable PSS, where a whole life cycle approach employing such strategies as product take back is adopted. Hence, further researches deepening the understanding on capabilities to support successful process are need. On this concern, recent research by Wilkens et al. (2016) declared as a critical field for PSS successful the hindering and supporting influence of managerial cognition, related to micro foundations in dynamic capability research. They investigated how managerial cognitions influence a firms' capability to realize PSS opportunities and to seize and reorganize its resources in order to take competitive advantage. They found that PSS are nor primarily considered as opportunities but rather threats with different strategies of coping mechanisms. In short, based on furthers research appointed by studies of systematic review, the mains perspectives for research on SPSS in manufacturing SMEs are the following:

Table 7: Mains research directions

Dimension	Mains research topics on SPSS in SMEs
SPSS transition	Development of frameworks or protocol to realize the risk, cost and profit analysis of SPSS offer and transition. A consolidation of comprehensive collectanea of SPSS cases and examples to improve the overall understanding of SME on impact of this business model. Researches proposing mechanisms to help SME to determine the fit and necessary organizational changes involving in the SPSS transition.
SPSS modelling	Development of systematic and structured artifacts (i.e. models, method) guiding and supporting the detailing of offer along all stages of life of PSS (Beginning of Life, Middle of Life, End of Life). Automatized artifacts based in software proposing business tools also are an alternative indicated. Combine scenarios with sustainable analysis and in PSS issues like business model, product, service and user life-cycles.
Empirical studies	Longitudinal empirical investigations in different industrial segments of SMEs should enable the development methodologies and tools suited to this context.
Internal Competences	Researches in order to define the core of capabilities necessary to support the SPSS transition. Frameworks to and tactics integrating know how of management and design fields in order to help SMEs to develop design leadership capabilities.
Circular Economy	Studies identifying connections of SPSS in SMEs into circular economy domain.
ICT	A general framework is needed to increase the consistency between the adoption of ICTs by SME internal areas and the business processes. Structured frameworks to help SME choice the more suitable ICTs for its reality.
TBL Sustainability	Develop a framework in order to support SME to define objectives using sustainable indicators. Development of suited tools to SMEs realizes the assessment of social and environmental impact of SPSS offer. Understand the relationship between social aspects concerned in manufacturing SMEs servitization process. Comprehend the impact of social factors in the economic, technical and environmental performance of SPSS offer.

The relation of further research topics obtained from literature analysis, reveal the mains issues that may be explored for academics. The proposition of artefacts suited to SMEs reality to performed different analysis and activities is a recurrent and necessary aspect noted by most part of studies. This can be partially explained by limited internal competences of small business. Other noted challenge to SMEs is consider the Triple Bottom Line (economic, social and environmental) along all steps of transition process.

On these concerns, Salazar et al. (2015) advocate that when the principal motivation for pushing the PSS to the market is the industry wanting to introduce a new offering, user needs are not well defined. The company proposing a novel offering in the market has more leeway to negotiate. However, when customer demands pull the market, usage and habits already exist and it is more difficult to change the market. Consequently, in this last case, to minimize the possibilities to failures, the literature propose as alternative strategy to company, realize the proposition of radical innovation offers based in previous and well tested socio-technical experiments (Mylan, 2015; Ceschin, 2014, 2013).

5.5 Discussion

The systematic review of literature shows several evidences of which the transition towards SPSS is not an easy journey and that many difficulties hinder a sustainable servitization to SMEs. This is partially explained by limited current research framework accumulating focused in SMEs context. The literature focused on this domain is scarce and consequently the operational deployment at the concrete level in manufacturing SMEs economy are very limited around the world (Clegg et al., 2017; Boucher et al., 2016). In this same line, it is possible verify that there are significant differences in innovation business models between large (i.e. resource abundance companies, focus on mid to long term planning, high degree of formalization) and SMEs (i.e. short term planning, low degree of formalization, resource poverty). Considering specially these intrinsic characteristics of SMEs, the SPSS transition can turn still more difficult.

In this sense, our research makes a relevant contribution to this topic offering several guidelines to small business. By analysing the content of the literature review identified, it was found that state of art of investigations on transition process to SPSS in capital goods manufacturing SMEs is organized in four distinct categories of tactics. These tactics are the following: studies on models supporting the transition, studies understanding how occurs the transition and suggesting guidelines, studies assessing the transition and publication developing specific tools for a sustainable transition.

The most of these studies are originally of Industrial Engineering and from Design area. Academics from Design area emphasized the human interfaces in systems design, while Industrial Engineering emphasized in pragmatic and oriented value proposition point of view on systems. In our opinion, and based in gaps of literature, researches integrating these two areas presents more potential to achieve robust SPSS models. In this direction, Tukker (2015) affirm that the mains detailed PSS design methods available in literature are not yet mature or that tools are still lacking, potentially leading to a lack of emphasis on requirements that should drive

PSS design. The results showed that this present problem is potentialized in SPSS transition in capital good manufacturing SMEs due the lack of reference methods oriented to small business.

Furthermore, results showed that this discussion is in very early stage of research perspective. Hence, the proposition of new methods, in this early stage of research on SPSS in SMEs domain, is a relevant and necessary step to advance in innovative SPSS methods oriented to manufacturing SMEs. Is recommended that these proposed artefacts be developed based on Design Science Research concepts (March and Smith, 1995; Dresch et al., 2015) showing clear and systematics instantiations in order to minimize the lack of knowledge faced by SMEs. Results suggested that EU funded projects are a solid environmental to conduct empirical based investigations.

The outcomes reveal that business context and the region in which the select studies were realized is concentrated in Europe, and specially in France, while only a few researches are directed in development economies and in of low-income countries. Recently, works in development economies and in of low-income countries has been conducted in a specific case of SPSS with strong socio-environmental motivation. As for instance, the case of Distributed Renewable Energy PSS business models in Africa and others countries (Emili et al., 2016; Vezzolli et al., 2015; Costa and Diehl, 2013). From analyse of limited business context investigates on previous literature, also emerges the opportunity of research projects involving the collaboration of different countries and academics, aiming to compare regional similarities/divergences. Furthermore, some barriers related with low value products resulting in low profit margins can be a very critical factor in low incoming economies or in developing nations, where the normally the customers considerer the criteria cost as determinant for purchase. To overcome this barrier, more radical innovations based in radical value proposition are need. This may contribute to advance in theory-building on SPSS transition in manufacturing SMEs in this specific context.

Regarding the research techniques and tools adopted in studies, findings shows that qualitative research techniques and tools, case study and workshop to validation of artefacts predominate. Outcomes evidence two mains categories of tools used to perform different tasks supporting SPSS transition process. In the first, several studies apply typical management tools (i.e. SWOT, PESTEL, scenarios analyses, BSC) and in second category, academics employ design and creative tools (i.e. Business Model Canvas and Design Thinking tools). Concerning to effectiveness of tools, results suggest that design tools are more suited to perform the conceptual design of SPSS offer than others techniques. This can be partially explained because they are hand on and flexible creative-based tools, realized in interactive process and workshops. These characteristics have a strong affinity with some typical characteristics of SMEs such as the flexible organization, the low degree of formalization and the short term orientation. Findings also demonstrate that scenarios help identify the most important risks during transition process, turning a lever to integrate the concepts of usage and sustainability.

Results also indicated more suited tools to stimulation and management of transition (i.e. scenarios and strategic, tactic and operational analysis) and to assessment (i.e. sustainability assessment, BSC, risk analysis). Specially, sustainability indicators can be applied in different levels and stages towards SPSS and can be considered a critical issue towards a SPSS transition (Kjaer et al., 2016; Sundin et al., 2015). Despite of societal analysis be cited in SPSS literature (Mylan, 2015; Ceschin, 2013) as a critical factor, none specific model or framework for societal impact analyses can be found to manufacturing SMEs. Eco-efficient PSS innovations usually encounter the opposition of the existing socio-technical context, because in most of the cases they require a change in the routine behaviours that are daily reproduced by individuals, groups, business communities, governmental institutions, and society at large (Ceschin, 2013; Tukker and Tischner, 2006). Therefore, these can be considered relevant research avenues for further investigations in small enterprises.

In addition, findings reveal that there is the understanding of which internal and external risks analysis are critical factors and that scenarios visualization help identify these most important risks towards a sustainable-oriented servitization. In order to support this transition process, also findings indicated that SMEs must develop clear objectives and suited selected indicators to their context. Besides, structured SPSS methodologies, the establishment of partnership and the engagement in networks are the most enablers towards a successful transition.

Another relevant contribution of our research is the consolidation of mains barriers towards SPSS in manufacturing SMEs. From analyses of results, forty four types of barriers were classified in seventeen categories. On the one hand, findings reveal expected internal barriers associates with intrinsic characteristics of SMEs as a whole, will become still more sensitive during the in SPSS transition. As for example, the lack of financial resources and financial vulnerability, the lack of managerial, design and sustainability competences, the follower mentality, the change resistance among others.

On the other hand, there are barriers directly related with the nature and novelty of PSS and SPSS business models that require new attitudes to be adopted by company. Such as change mind-sets from product ownership to use, the need of replace value of exchange by value in use involving long term relations, the lack of understanding of SPSS concept, the lack of models/method guiding the transition, among others. Tukker and Tischner (2006) stated that the firms have to assess carefully if they can competitively make and consumers will buy their PSS. As a consequence, the barriers associates with the characteristics of SMEs and the related with the novelty of SPSS need be carefully considered in an integrated manner.

A relation of several lessons learned from empirical studies was organized in guidelines format in order to mitigate the barriers faced by SMEs scaling-up a successful transition. In addition, based in analyses of barriers and lesson learned, an innovative matrix supporting the decision making process by SMEs during the transition process to SPSS was proposed (Fig. 3). Outcomes show that drivers moving towards a more sustainable-servictized company results in several competitive benefits. In summary, the drivers are related with economic motivation, need of differentiation, create market opportunities, meet customer demand and sustainability.

Particularly, the motivation on sustainability is based in a strong belief in PSS helping to become more sustainable and this normally occurs when the SME has past activities in this direction. These results are corroborated by previous literature. According to Tukker and Tischner (2004; Sundin et al., 2015), the main motivations are related to business and sustainability. In the first case, the driver has been considered a way to offer integrated high value solutions to attend market demands, putting the company in a better competitive position into the value chain. While the second refers to enjoy the sustainable potential of PSS.

In addition, the mains benefits and advantage in SPSS transition are the increase of competitiveness, sales, customer’s loyalty and satisfaction and the firm become more sustainable. Moreover, the restricted dimension and dynamism/flexibility when reflected in a fluid internal/external communication process, are enablers of SPSS transition. These factors allow them more easily to manage changes and develop responsibly towards servitization.

In summary, based in results of literature and aiming to support small companies to make the shift towards more service-oriented solutions, it is possible propose corollaries obtained from transversal analyses of select studies on SPSS transition in manufacturing SMEs. The corollaries are the following:

- Corollary 1: The transition process towards SPSS must be realized incrementally instead radically.
- Corollary 2: The engagement of manufacturing SMEs in partnership and networks to develop the SPSS offers has potential to minimize the competence gaps and enable more innovative, complete and competitive value proposition to customers.

These strategic transition rules also are corroborated by external literature on SME economy, and now become more sensitive. Studies reveal that SMEs have to join their efforts together in order to overcome these limitations through collaboration (Boucher, 2012; Bos-Browers, 2010). Engaging in networks is very helpful by allowing each other to mutually learning from each other at PSS introduction and further development (Pardo, 2012; Orloff and Heinz, 2015). Hence, to establish external partnership and stakeholder interactions, involving for example, large companies, suppliers, entities, governmental, universities, SMEs partners and consulting, will help SMEs to develop robust value proposition to customer.

The transformations must be realized in gradually and incrementally manner, instead of a fast transformation, mainly due theseveral constraints associated with lack of internal competences (i.e. in design, sustainability, management) and financial. This limited competence also turn more difficult to SME comprehend external factors, such as customer/user existing behaviours and lifestyle, how the service provider is perceived, regulatory challenges, financial reasons, among others. Lastly, in this sense, is noted that these two rules are related each other, because the intensity of engagement of manufacturing partnership/networks can impact in the velocity of their transition towards SPSS. Our analysis of the relevant literature revealed a very recent movement of studies investigating the transition towards SPSS. The added value of this systematic review is in the structures proposed which highlight interesting insights enriching the stock of knowledge on transitions towards SPSS in manufacturing SMEs field.

5.6 Conclusion and further research

For some decades PSS have been known and acknowledged as effective means towards more sustainable production. However, despite several singular initiatives, PSSs have still not been implemented widely. Possible reasons for this failure to disseminate the concept are related with the lack of inappropriate supporting methods and tools (Annarelli et al., 2016; Ceschin, 2014; Cavalieri and Pezzotta, 2012; Tukker and Tischner, 2006) and the lack of acceptance of consumers (Vezzoli et al., 2012; Tukker and Tischner, 2006; Oman, 2003; Tukker, 2015). These related reasons become more critical in the environment of manufacturing SMEs, characterized by limited capabilities and resources.

Originally the PSS was developed as a more sustainable alternative to traditional product-sales, especially through better and more intensive use of materials. From this logic, by shifting from traditional offer to an integrated solution of product-services, it was expected that PSS could reduce the environmental impact and provide benefits for provider and for consumer in economic and social ways (Sundin et al., 2015). However, currently there is in the literature the understanding that the sustainability (TBL) is not an intrinsic characteristic of PSS (Doualle et al., 2015; Pigosso and McAloone, 2016; Boucher et al., 2016). And consequently, abroad this discussion, a perspective defined as “Sustainable Product-Service Systems (SPSS)” has received attention from scholars.

The literature also reveal which the transition process towards SPSS is not an easy journey. Several difficulties hinder a sustainable servitization to large and especially to SMEs (Vezzoli et al., 2015; Salazar et al., 2015; Pardo et al., 2013; Orloff and Heinz, 2015). A clear disadvantage to small business is that the most part of existent literature focus mainly on large enterprises overlooking the significant contribution of SMEs to the global economy. Many researchers reported experiments in large enterprises, typically specialized in functional goods production, while only few researches have been performed for SMEs (Tonelli et al., 2009). Furthermore, it is clear that some intrinsic characteristics of SMEs such as lack ok capabilities, financial gaps, short term planning, turn the transition still more difficult.

Therefore, considering that the existing fragmented and insufficient background regarding SPSS transition in SMEs do not support a fluid transition process, our study aimed to comprehend the factors involving the transition towards SPSS into practice. To fill this relevant research gap, we identified the mains previous studies on this domain, the mains research techniques, methods and tools applied in transitions cases. Findings also have clarified the benefits, barriers and strategic guidelines to overcome these barriers during the transition. A set of fourth four types of barriers were classified in seventeen categories, and forty four guidelines to overcome these barriers were organized in fifteen categories in an innovative matrix supporting decision making. As result, our study provides a structured and comprehensive review of literature and several insights from empirical rooted selects studies. Identifying and discussing several empirically rooted examples of tactics and their related aspects provide further guidance to companies that are in the process of gaining value from implementing a PSS business model (Reim et al., 2015).

Comparing with traditional PPS offers, the challenges faced by manufacturing SMEs to a sustainable (TBL) transition found several factors in consonance. These challenges involve, for instance, the general difficulty in the transition from the traditional business model of selling products to a service and value-oriented model (Kowalkowski et al., 2017; Cook, 2014). This shift increase the vulnerability in SMEs due its limited resources available and internal lack of specific competences in management and particularly SPSS related competences, such as in sustainable and design capabilities. Normally, large companies can more easily obtain and internalize this type of competence because dispose of more resources for mobilization.

Other critical challenge faced is regarding the existence of effective and suited method/tools supporting the transition stages along the life cycle of PSS (Meier et al., 2010; Cook, 2014; Cavalieri and Pezzotta, 2012). The outcomes and gaps from consolidated PSS literature evidenced that the most part of available methodologies are best suited for large companies. Furthermore, for a successful exploration and use of these methodologies generally is necessary the external support guiding the application of tools and conducing the internal analysis of company in transition journey. Several methodologies with this intention were developed in past years within EU funded projects oriented to large companies. Accordingly, the routine of application and internalization of these approaches need of support of a project member or a consultant, mainly on SMEs context.

Our results shown that an alternative aiming a more fluid internalization of methodologies to SPSS transition in SMEs begins with the adoption the hand-on approaches. The realization of in-company workshops in SMEs detailing the process seems be is a good strategy in order to obtain engagement and internal mobilization, and perhaps the beginning of a wide change of internal mind-sets. In this direction, also is indicated the use of tools with potential to explore the responsiveness and low bureaucratic advantages of SMEs context (Bos-Browers et al. 2010), since organized in a structured process and method. "The use of individual Design Thinking tools had not provided a route to deliver the product-and service-innovation required; what was missing was a method to combine the individual tools to create a process" (West and Nardo, 2016, p. 96). Our findings showed that the connection between service engineering structured tools with Business Model Canvas or Design Thinking approaches results in more effective methods supporting transition and helping to internalize some required competences in SMEs (Xing and Ness, 2016; Orloff and Heinz, 2015; Pardo, 2012).

Regarding to avenues for future research, the mains perspectives aiming establish an evolutionary framework on SPSS in manufacturing SMEs might be summarized into categories. In SPSS transition and modelling category, important research directions are related with the proposition of artifacts (i.e. frameworks, models, methods) to made the risk, cost and profit analysis, to measure and help SME to conduce the organizational changes, to systematically define and detail the SPSS offer along the life cycle, and also artifacts helping the realization of sustainable analysis using scenarios. On the whole, more prescriptive studies are necessary.

In the empirical studies category, remains the opportunity of longitudinal and cross-sectors empirical studies looking for transition patterns and best practices. In this sense, research projects involving the collaboration of different countries and academic communities, aiming to compare regional similarities/divergences are a possibility. Further researches on internal competences could be concentred to determine the core of minimum capabilities necessary to support the transition as well as approaches to unlock design and sustainability leadership capabilities.

In ICT categories, research efforts are need to develop frameworks guiding SMEs choice more suitable ICTs and increase the diffusion internally. The increasing role of Industry 4.0 (i.e. digitalization, IoT, Big Data and so on) and the number of potential companies in low-income countries also represent new areas that are currently opening up for research efforts in SPSS. Researches specific on Sustainability (TBL) should be aligned to comprehend the social aspects and their impact on economic and environmental dimensions. Suited low complexity/quantitative assessment tools aiming measure social and environmental impact also are lacking. Identify connections of SPSS in SMEs into circular economy also is an emergent opportunity.

Although the results of this research contribute to advance in theory-building on SPSS transition in SMEs, certain limitations should be considered. Initially, the selected studies consider empirical researches investigating the transition process to SPSS specifically in capital goods SMEs, as well as qualitative studies proposing artifacts and results in this field. Others eligibility criteria could eventually be adopted for selection. Second, studies written in a language different than English have been excluded. This research also used only formal literature available in scientific databases, does not including books or grey literature.

Recent comprehensive studies also corroborate the relevance and contribution to theory-building of this research. The extensive analysis of stat-of-art on servitization in Baines et al. (2017) suggests the increasing of global awareness on the importance of services to manufacturers. However, some topics, especially related to servitization transformation, remain undeveloped. In addition, the service growth in product firms is one of the most active service research domains and still is open to a variety of conceptualizations (Kowalkowski et al., 2017). In this sense, this reserach contributes extending the current theory framework on SPSS in SMEs driving new researches avenues to this domain.

“Because of the potential of SPSS to deliver social well-being and economic prosperity while operating within the limits of our planet, the research community has been inspired to analyse cases in diverse sectors, to increase the understanding of the potential benefits, drivers and barriers, and to develop and to test methods and tools to be able to enhance the array of SPSS that are implemented globally. This is urgently needed because, despite all the knowledge and experience that has been accumulated, there remain gaps in the research as well as a significant gap in how all this knowledge is transferred to implementation" (Vezzoli et al. 2015, p. 3). In this sense, the relevance of this study is presented new insights to capital goods SME' managers, policy makers and academic community in order to successful implement SPSS business models.

REFERENCES

Annarelli, A., Battistella, C., Nonino, F. 2016. Product service system: A conceptual framework from a systematic Review. Journal of Cleaner Production 139: 1011-1032.

Baines, T., Bigdeli, A. Z., Bustinza, O.F., Shi, V.G., Baldwin, J.,Ridgway, K. 2017. Servitization: Revisiting the State-of-the-art and Research Priorities. International Journal of Operations & Production Management, in press.

Baines, TS, Lightfoot H, Steve E, Neely A, Greenough R, Peppard J, Roy R, Shehab E, Braganza A, Tiwari A, Alcock J, Angus J, Bastlm M, Cousens A, Irving P, Johnson M, Kingston J, Lockett H, Martinez V, Michele P, Tranfield D, Walton I, Wilson H. 2007. State–of–the–art in product service systems. In: Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221(10): 1543-1552.

Barquet, A. P., Seidel, J., Buchert, T., Galeitzke, M., Neugebauer, S., Oertwig, N., Rozenfeld, H., Seliger, G. 2016b. Sustainable product service systems – from concept creation to the detailing of a business model for a bicycle sharing system in Berlin. Procedia CIRP 40: 524 – 529.

Barquet, A. P., Seidel, J., Seliger, G., Kohl, H. 2016a. Sustainability factors for PSS business models. Procedia CIRP 47: 436 – 441.

Berisha, G., Pula, J. S. 2015.Defining Small and Medium Enterprises: a critical review. Academic Journal of Business, Administration, Law and Social Sciences 1 (1): 17-28.

Beuren, F.H., Ferreira, M.G.G., Miguel. P.A.C. 2013. Product–service systems: a literature review on integrated products and services. Journal of Cleaner Production 47: 222-231.

Bos-Brouwers, H. E. J. 2010. Corporate Sustainability and Innovation in SMEs: Evidence of Themes and Activities in Practice. Business Strategy and the Environment. 19 417–435.

Boucher X. (2012) Economic and Organizational Transition towards Product/Service Systems: The Case of French SMEs. In: Camarinha-Matos L.M., Xu L., Afsarmanesh H. (eds) Collaborative Networks in the Internet of Services. PRO-VE 2012. IFIP Advances in Information and Communication Technology, vol. 380. Springer, Berlin, Heidelberg.

Boucher, X., Brissaud, D., Shimomura, Y. 2016. Editorial: Design of sustainable product service systems and their value creation chains. CIRP Journal of Manufacturing Science and Technology 15: 1–2.

Cavalieri, S., Pezzotta, G. 2012. Product–Service Systems Engineering: State of the art and research challenges, Computers in Industry, 63 (4), 278–288.

Ceschin, F. 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production 45: 74-88.

Ceschin, F., 2014. How the design of socio-technical experiments can enable radical

changes for sustainability. Int. J. Des. 8 (3), 1- 21.

Clegg, B., Little, P., Govette, S., Logue, J. 2017. Transformation of a small-to-medium-sized enterprise to a multi-organisation product-service solution provider. International Journal of Production Economics. In press.

Cook, M. 2014. Fluid transitions to more sustainable product service systems. Environmental Innovation and Societal Transitions 12: 1–13.

Costa, J.C., Diehl., J.C 2013. Product–service system design approach for the base of the pyramid markets: practical evidence from the energy sector in the Brazilian context

Doualle, B., Medini, K., Boucher, X., Brissaud, D., Laforest, V. 2016. Design of sustainable product-service systems (PSS): towards an incremental stepwise assessment method. Procedia CIRP 48:152–157.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research:A Method for Science and Technology Advancement. Springer. pp.161.

Emili, S., Ceschin, F., Harrison, D. 2016. Product–Service System applied to Distributed Renewable Energy: A classification system, 15 archetypal models and a strategic design tool. Energy for Sustainable Development 32:71-98.

European Comission (2016). User guide to the SME Definition. Available in: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/

European Commission. 2011. Minimizing Regulatory Burden for SMEs. Adapting EU Regulation to the Needs of Micro-Enterprises. Final report. European Commission: Brussels, Belgium, 2011.

Halme, M., Jasch, C., Scharp, M., 2004. Sustainable home services? Toward household services that enhance ecological, social and economic sustainability. Ecological Economics 51 (1 e 2), 125 - 138.

IPSS business model development. Procedia CIRP 47:495 – 500.

Kjaer, L.M., Pagoropoulos, A., Schmidt, J. H., McAloone, T.C.2016. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. Journal of Cleaner Production 120, 95-104.

Kowalkowski, C., Gebauer, H., Oliva, R. 2017. Service growth in product firms: Past, present, and future, Industrial Marketing Management 60 (1): 1-7.

Kowalkowski, C., Witell, L. & Gustafsson, A. 2013. Any Way Goes: Identifying Value Constellations for Service Infusion in SMEs. Industrial Marketing Management 42 (1): 18–30.

Lelah, A., Boucher, X., Moreau , V., Zwolinski, P. 2014. Scenarios as a Tool for Transition towards Sustainable PSS. Procedia CIRP 16: 122 – 127.

Lelah, A., Mathieux, F., Brissaud, D., Vincent, L. 2012. Collaborative network with SMEs providing a backbone for urban PSS: a model and initial sustainability analysis. Production Planning and Control 23:299-314.

March, S. T. and Smith, G. F. 1995. Design and natural science research on information technology. Decision Support Systems 15 (4): 251-266.

Maxwell, D., van der Vorst, R. 2003. Developing sustainable products and services. Journal of Cleaner Production 11: 883–895.

McCormick, K., Neij, l., Mont, O., Ryan, C., Rodhe, H., Orsato, R. 2016. Advancing sustainable solutions: an interdisciplinary and collaborative research agenda. Journal of Cleaner Production 123: 1-4.

Meier, H., Roy, R., Seliger, G., 2010. Industrial product-service system e IPS2. CIRP Ann. e Manuf. Technol. 59: 607- 627.

Micro perspectives for decentralized energy supply. Conference Proceedings, Technische Universität, Berlin.

Mitchell, S., 2014. A sustainability and eco-innovation framework for manufacturing SMEs. Doctor of Phlilosophy in Mechanical and Industrial Engineering, Galway-Mayo Institute of Technology.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. 2009. The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097.

Mongeon P, Paul-Hus A. 2016. The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics 106 (1):213-228.

Moore, S., Manring, S. 2009. Strategy development in small and medium sized enterprises for sustainability and increased value creation, Journal of Cleaner Production 17: 276–282.

Mylan, J. 2015. Understanding the diffusion of Sustainable Product-Service Systems: Insights from the sociology of consumption and practice theory. Journal of Cleaner Production 97:13-20.

Nada, N., Ali, Z. 2015. Service value creation capability model to assess the service innovation capability in SMEs. Procedia CIRP 30: 390 – 395.

OECD. 2010. High-Growth Enterprises: What Governments Can Do to Make a Difference. OECD Studies on SMEs and Entrepreneurship, OECD Publishing. http://dx.doi.org/10.1787/9789264048782-en

Oliva, R., Kallenberg, R. (2003). Managing the transition from products to services. International Journal of Service Industry Management 14 (2): 160–172.

Omann, I. 2003. Product-service systems and their impacts on sustainable development – a multi-criteria evaluation for Austrian companies. Frontiers, 1-34.

Orloff, D., Heinz, S. M. 2015. Sustainable product service systems in small and medium enterprises - from a case study on textile leasing to a Design Thinking Workshop for Sustainable Product Service System Development for Sustainable Product-Service System Development. Master Thesis in Sustainability Science. Universitat Luneburg. 160 p.

Paiola, M., Gebauer, H., & Edvardsson, B. (2012). Service Business Development in Small- to Medium-Sized Equipment Manufacturers. Journal of Business-to-Business Marketing 19 (1): 33–66.

Pardo, H. R.J., Bhamra, T., Bhamra, R. 2012. Sustainable Product Service Systems in Small and Medium Enterprises (SMEs): Opportunities in the Leather Manufacturing Industry. Sustainability 4: 175-192.

Pardo, H.R.J. 2012. Designing Sustainable Product Service Systems: a business framework for SME implementation. Doctor of Philosophy, Loughborough University, 358 p.

Pardo, H.R.J., Bhamra, T., Bhamra, R., 2013. Exploring SME perceptions of sustainable product service systems. Engineering Management, IEEE Transactions 60: 483–495.

Pigosso, D.C.A., McAloone, T.C. 2016. Maturity-based approach for the development of environmentally sustainable product/service-systems. CIRP Journal of Manufacturing Science and Technology 15: 33–41.

Qu, M., Yu, S., Chen, D., Chu, J., Tian, B. 2016. State-of-the-art of design, evaluation, and operation methodologies in product service systems. Computers in Industry 77: 1-14.

Raddats, C., & Easingwood, C. (2010). Services growth options for B2B product-centric businesses. Industrial Marketing Management 39 (8): 1334–1345.

Rapitsenyane, Y. 2014. Supporting SMEs adoption of sustainable Product Service Systems: a holistic design-led framework for creating competitive advantage. PhD thesis, Dessign School, Loughborough University, UK.

Reim, W., Parida, V., Ortqvist, D. 2015. Product e Service Systems (PSS) business models and tactics e a systematic literature review. Journal of Cleaner Production 97, 61-75.

Salazar, C. , Lelah, A., Brissaud, D. 2015. Eco-designing Product Service Systems by degrading functions while maintaining user satisfaction. Journal of Cleaner Production 87: 452-462.

Salazar, C., Lelah, A., Brissaud, D. 2015.Eco-designing Product Service Systems by degrading functions while maintaining user satisfaction. Journal of Cleaner Production 87:452-462.

Sebrae, 2015. Available in: https://www.sebrae.com.br/sites/PortalSebrae/estudos_pesquisas/conjuntura-economicadestaque10,0a080b91762b3410VgnVCM1000003b74010aRCRD

Song, W., Sakao, T. 2017. A customization-oriented framework for design of sustainable product/service system. Journal of Cleaner Production 140: 1672-1685.

Sundin, E., Elin, N., Lelah, A. 2015. Sustainability indicators for Small and Medium-sized Enterprises (SMEs) in the transition to provide Product-Service Systems (PSS). Procedia CIRP 30: 149 - 154.

Tonelli, F., Taticchi, P., Sue, E.S. 2009. A Framework for Assessment and Implementation of Product-Service Systems Strategies: Learning From an Action Research in the Health-Care Sector. WSEAS TRANSACTIONS on BUSINESS and ECONOMICS 7 (6): 3020-319.

Tranfield, D., Denyer, D. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Tukker, A. 2015. Product services for a resource-efficient and circular economy - A review. Journal of Cleaner Production 97: 76-91.

Tukker, A., Tischner, U., 2006. Product-services as a research field: past, present and future. Reflections from a decade of research. Journal of Cleaner Production 14 (17), 1552-1556.

Vasantha, G., Roy, R., Lelah, A., Brissaud, D. 2012. A review of product-service systems design methodologies. Journal of Engineering Design, 23 (9): 635-659.

Vasantha, G.V.A., Roy, R., Corney, J.R. 2015. Advances in Designing Product-Service Systems. J. Indian Inst. Sci. 95, 429-447.

Vezzoli, C., Ceschin, F., Diehl, J.C., Kohtala, C.2012. Why have 'Sustainable Product-Service Systems' not been widely implemented? Meeting new design challenges to achieve societal sustainability. Journal of Cleaner Production 35: 288-290.

Vezzoli, C., Ceschin, F., Diehl, J.C., Kohtala, C.2015. New design challenges to widely implement 'Sustainable Product e Service Systems'. Journal of Cleaner Production 97: 1-12.

Wilkens, U., Lienert, A., Elfving, S.W. 2016. The relevance of managerial cognition for

Xing, K., Ness, D. 2016. Transition to product-service systems: principles and business model. Procedia CIRP 47: 525–530.

Yang, M., Evans, S., Vladimirova, D., Rana, P. 2017. Value uncaptured perspective for sustainable business model innovation. Journal of Cleaner Production 140: 1794 – 1804.

CAPÍTULO V

The main implications and contributions of this Chapter to this thesis were the following:

- Results showed that the research topic focusing on the systematic SPSS transition is far from being a mature research topic.
- There are no currently methodologies, methods or even reference models or methods accepted between the academics and professionals evolving in the servitization field. Thus, the systematic innovation proposals of TRIZ may contribute to fill this research gap, enabling more systematic and Sustainable PSS business models supported by structured methods.
- The proposition of new methods is a relevant and necessary step to advance towards effective SPSS business models, allying sustainable innovations and reduction in environmental impacts.
- Were identified guidelines about how the systematic methods and tools of TRIZ may be applied in the transition towards Systematic and Sustainable PSS (SSPSS) contributing to a more efficient and systematic servitization process.
- Aiming to expand the adoption of radical eco-innovations integrating TRIZ in SPSS it is necessary that artifacts have clear and detailed instantiations. Detailed instantiations, particularly within new and well organized TRIZ methods, are specially recommended.
- The most suitable systematic methods and tools for SPSS design proposals and develop radical innovations in SMEs were mapped.
- This chapter presents the main systematic advances, contributions and tools to develop the proposed method to SPSS proposal oriented to eco-innovation in SMEs.

6 Artigo 5: Towards Sustainable Product-Service Systems: Systematic Review on the role of Theory of Inventive Problem Solving

Abstract

The sustainable servitization process is not an easy journey. The literature shows positive and several negative aspects on this transition. To obtain successful towards Sustainable Product-Service Systems (SPSS) research gaps in the literature pointed the need of well-structured methods to support systematic eco-innovations and solve the contradictions during this process. The Theory of Inventive Problem Solving (TRIZ), in turn, is worldwide recognized by the potential in solve contradictions and systematically create innovations. However, the research framework available and its application in PSS field are very limited. Thus, the main purpose of this paper was to explore how the TRIZ may be applied in the in servitization process to achieve efficient SPSS design. A systematic literature review between 1995 and 2015 was conducted covering the main scientific databases providing a comprehensive critical review of foundations and recent developments in this topic. The primary results allowed identify the contributions about TRIZ in SPSS, the main eco-innovations resulting, the artifacts (models, methods, proposition or instantiation) that applied TRIZ in servitization, and the most frequent type of PSS that adopt TRIZ. The conclusion pointed is which the systematic innovation proposes of TRIZ has great potential to enable Systematic and SPSS (SSPSS). The scientific value added of our study contributes to the servitization field extending the current literature by providing important insights and challenges in SPSS design applying the TRIZ methodology. A research agenda was proposed to advance in the current research framework.

Keywords: Product-Service Systems. Servitization. TRIZ.Sustainable PSS. SPSS. Eco-innovation.

6.1 Introduction

Cleaner Production practices may not result in a transformation in the short term without the integration of environmental, economic and social dimensions to innovations in the companies' managerial systems (Almeida et al., 2017). The term Cleaner Production was defined by UNEP in 1990 as: “The continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment" (Fresner et al., 2010). In this context, also is noted that: "The concept of developing sustainable products as well as services is evolving as a key element of Cleaner Production" (Maxwell and Vorst, 2003, p. 883).

However, the transition toward Product-Service Systems (PSS) is not an easy journey, and many difficulties hinder a sustainable servitization process (Kjaer et al., 2016; Vezzoli et al., 2015; Salazar et al., 2015). Studies have demonstrated that PSS business models in certain cases may indeed have a negative effect on the environment and only result in economic benefits (Barquet et al., 2016; Tukker, 2015; Doualle et al., 2015).

"Simply replacing product selling for service offer might not be enough to lead to more sustainable solutions. Contradictions and incoherencies hinder the potential of PSS business models to provide sustainability benefits and might be a barrier" (Barquet et al., 2016, p. 436-437). For instance, barriers and contradictions between different sustainability targets arise during the servitization process (Omann, 2003). Lelah et al. (2014) indicated that the adoption of eco-efficient PSS is more complex, among other reasons, because changes in corporate culture and organizations are needed to support a more systemic innovation and service-oriented business (Ceschin, 2013). Findings from literature review studies (Vasantha et al., 2015; Beuren et al., 2013; Vasantha et al., 2012) indicated that reasons for this failure were associated with the lack of acceptance by consumers and the lack of inappropriate supporting methods and tools for companies. Navas (2014, p. 82.) also corroborate these findings stating that: "[…] enterprises need to invest in systematic eco-innovation if they plan to win or at least survive".

As a consequence, aiming to minimize problems associated with the need to support systemic innovation (Ceschin, 2013; Omann, 2003) and to solve contradictions and incoherencies (Barquet et al., 2016; Qu et al., 2016) during the servitization process, one alternative is the adoption of systemic innovation methods and tools to sustain a fluid transition process throughout the PSS stages. Specifically, structured methods are needed because systematic innovation methods for sustainable design reduce innovation risks (Kim and Park, 2012). In this direction, certain recent studies have investigated a promising framework applying systematic methods and tools of TRIZ methodology to obtain sustainable innovations solving contradictions in Sustainable PSS (SPSS) design.

TRIZ is a Russian acronym for *Teoriya Resheniya Izobretatelskikh Zadatch* which, when translated into English, means Theory of Inventive Problem Solving. It is recognized worldwide to have the capability to solve contradictions and systematically generate innovations (Kim and Yoon, 2012). TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in systems, in the design and problem solving through the elimination or attenuation of the contradictions found (Altshuller, 1999).

Prior studies that have been published in specialized journals in the field of sustainable innovation, such as the Journal of Cleaner Production and others provided evidence regarding the potential of TRIZ in sustainability in different topics, such as on eco-innovation (Yang and Chen, 2011; Vidal et al., 2015), eco-design (Russo et al., 2014) and cleaner production solutions (Kubota and Rosa, 2013; Fresner et al., 2010). Fresner et al. (2010, p. 130), stated that TRIZ applications to the design of products in cooperating sustainability and eco-efficiency related problems are rarely documented in the literature. Nevertheless, although these studies demonstrated the potential of TRIZ in different topics on sustainability and cleaner production, none study is focused specifically on the transition towards SPSS business models.

Furthermore, several contradictions and incoherencies appear during the servitization journey blocking the expected benefits of new service offer. As consequence, according to literature, more systematic and structured managerial methods and tools must be adopted along with the servitization process (Rondini et al., 2016; Qu et al., 2016; Cavalieri and Pezzotta, 2012) to mitigate, for example, the barriers associated with the “lack of knowledge within firms” (Vezzoli et al., 2015, p. 8). In addition, from the customer perspective, findings from the literature show that: “In the transition process toward PSS, manufactures need the assistance of tools, techniques, and methods to provide superior service to customers” (Qu et al., 2016, p. 4). In short, all these research gaps reinforce the potential and need of the adoption of systematic methodologies, during the servitization process, such as the TRIZ proposes in its body of knowledg.

Besides these aspects, the novelty and scientific contribution of our study also is corroborated by previous systematic literature review studies on TRIZ methodology. Findings from comprehensive literature review studies confirm that insights regarding how companies may adopt TRIZ to obtain a more systematic and sustainable servitization process are still very limited (Chechurin and Borgianni, 2016; Sperafico and Russo, 2015). As a result, there is in the scientific literature an absence of structured frameworks enabling a sustainable servitization transformation process (Moussa et al., 2017; Lin et al., 2016).

Thus, considering the need to support systemic innovations (Ceschin, 2013) and solving contradictions (Barquet et al., 2016) during the servitization process highlighted by literature, a primary hypothesis of this study is that the systematic innovation methods proposed by TRIZ can fill these gaps. As well as, enable more efficient SPSS, resulting in a Systematic and Sustainable Product-Service Systems (SSPSS) design process. Based in this landscape and in the alignment between the TRIZ proposal and the research gaps from PSS literature, we introduced a definition to better comprehend the SSPSS domain defining as “an emerging technical discipline focused in the use of systematic and structured methodologies for elimination of the contradictions and generation of systematic innovations along the SPSS development.”

Therefore, based on these research gaps above, the purpose of our research is to comprehend the existent research framework available identifying what are the contributions and challenges of the adoption of TRIZ to obtain a fluid transition towards Sustainable PSS. The primary contribution of our research is that a structured aggregation and understanding of tactics within the TRIZ in PSS literature can help companies successfully design and implement Sustainable PSS business models resulting in economic and environmental benefits. In alignment with the relevance of this study, recently Reim et al. (2015, p. 62) stated: “[…] there is an increased need to synthesize the findings of existing studies and provide directions for future research on the important topics of PSS business models and tactics.” This situation has occurred because the rapid growth of the researches in this field, contributes to problems associated with accumulating and systematizing research findings.

Hence, a systematic literature review of studies that were published between 1995 and 2015 was conducted following the research protocol and steps proposed by Dresch et al. (2015). According to Tranfield et al. (2003), Dresch et al. (2015) and Liberati et al. (2009) a systematic literature review contributes to the development of a solid knowledge base that: (i) facilitates theoretical development for areas in which research has already been conducted, and (ii) allows the identification of opportunities for future research.

The process conducted by systematic review primarily addressed the following structural dimensions and related analytic categories: what are the contributions and gaps of TRIZ applications in sustainable PSS context; how TRIZ methods have been used for the three categories of PSS (product-oriented, use-oriented and result oriented); what are the main types and context of eco-innovation that included the application of TRIZ into SPSS; the most relevant research challenges and research opportunities to advance this topic.

The remain of this paper is structured as follows. Section 2 discusses the primary definitions of TRIZ and SPSS. Section 3 details the method and steps utilized in the study. Section 4 provides the results from systematic the review and in Section 5 includes a detailed discussion that summarizes the primary results and implications including the strength of evidence for the primary outcomes of research. Finally, Section 6 discusses and consolidates the main challenges to this research topic and Section 7 provides the conclusions, limitations and research agenda to advance in this field.

6.2 TRIZ and Sustainable PSS

TRIZ is not based on the spontaneous creativity and intuition of individuals, as the name would suggest. It is a disruptive technology that demonstrates that the skills to be creative and innovative can be learned (Ikovenko and Bradley, 2004). "TRIZ offers very strong tools for developing process improvement options on a generic level without specific technological knowledge about the process which shall be improved" (Fresner et al., 2010, p. 128). The approach can be applied in several contexts, such as in services, risk management, scientific research, business management, management strategic analysis of causes, research and development, technology foresight, educational planning, public relations, advertising, among others (Altshuller, 2004).

At the beginning of the process of analysis of a system, it is faced a situation involving inconsistencies or contradiction that need to be clarified, which can be eliminated by modifying the system or one of its subsystems (Navas, 2014). Fresner et al. (2010) stated that the process of inventing means to locate contradictions in a system, which keeps it from performing according to the ideal solution, and to solve them. Contradictions can be either technical, or physical. Technical contradictions appear when there are conflicting requirements regarding two different parameters of a technical system (e.g. the display of a laptop should be bright, and the life of the battery should be long, at the same time). Physical contradictions appear, when the same parameter should show different properties at the same time. For example, a coffee mug should be hot (to keep the coffee hot) and cold at the same time (to allow to touch it).

A PSS, on the other hand, provide a promising opportunity for industries to propose both prosper and eco-friendly solutions to fulfill the consumer needs (Cavalieri and Pezzotta, 2012) and make use of a new service structure to facilitate sustainable production and consumption (Tukker and Tischner, 2006). The design and development of a PSS raise new issues since the service component introduces further requirements than traditional product engineering (Cavalieri and Pezzotta, 2012).

By shifting from traditional offer, comprised of physical products, to an integrated solution of product and services, it is assumed that PSS may reduce the environmental impact and provide benefits for the PSS provider and the consumer in economic and social ways. However, sustainability is not an intrinsic characteristic of PSS (Doualle et al., 2015). Recently, in this discussion, a new perspective based on Sustainable Product-Service Systems (SPSS) has received attention from researchers and practitioners. To Barquet et al. (2016) SPSS business model is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilization and dematerialization, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage.

In literature available on PSS and TRIZ only a few studies focused on sustainable initiatives or eco-innovations resulting of adoption of TRIZ in PSS. To Rennings (2000), Kemp and Foxon (2007) and Arundel and Kemp (2010) eco-innovation can be defined as the production, application or exploration of goods, service, production process, organizational or managerial structure or method of business new to the enterprise or to the customer (OECD, 2009). The desired outcomes are reduced environmental risks, less pollution, and fewer negative impacts of the utilization of resources when compared to the corresponding alternatives.

Chen and Li (2010), for example, collected and analyzed 103 PSS cases and divided into eight categories to develop a model to identify consumers' use habits. Design tables were formulated and used as tools for obtain environmental innovation in PSS design. Chen and Huang (2011) show an eco-innovative design methodology to support designers in developing PSS by using functional analysis and the TRIZ Substance-field model. Studies also have tried to apply TRIZ in PSS design focusing on applying the Inventive Principles directly for PSS innovation, without using the Contradiction Matrix, while the principles are either identified through innovation rules or reinterpreted and transformed to suit for PSS concept generation (Yang and Xing, 2014).

In Pezzota et al. (2011) the Laws of Technical Systems Evolution, Evolution Trends and Ideality are used to predict what are the most likely improvements that can be made to a given PSS. As Shih et al. (2009) the Inventive Principles can be used to generate new PSS ideas. The authors also suggest identifying the Ideal Final Result for PSS innovation based on Trend of Evolution. Chen and Liu (2012) proposed a PSS Substance-field model by using information from the results of system layer analysis map, to obtain innovative and improvement low-carbon PSS ideas from TRIZ standard solutions.

To Low et al. (2001) the greening of individual products is made based on energy, resource, and pollution reduction. The parameters found in the TRIZ Contradiction Matrix are used to the generation of solutions that address the reduction of such factors. The TRIZ principles of resolution of physical contradictions (i.e. separation in time, system structure and parts) may also be employed to drive the innovative process toward the grouping of functions and technologies required during the design of services. In Chen and Jiao (2014) is made the relationship of product's characteristics factor level table of eco-leasing and TRIZ parameters, to find the new ideas for developing sustainable eco-leasing PSS. The systematic review protocol is detailed in next section.

6.3 Research Method

A systematic review of the literature is necessary to understand the state of the art aspects regarding this research topic and to identify pertinent information (Dresch et al., 2015; Tranfield et al., 2003; Gough et al., 2012). Literature reviews usually aim at two objectives. The first is summarize existing research framework of a research field by identifying patterns, themes, and issues. Second, they help to identify the conceptual content of the field and can contribute to theory development (Meredith, 1993). From the point of view of research methods, literature reviews studies can be comprehended as content analysis, where quantitative and qualitative aspects are mixed to assess structural or descriptive data, as well as content criteria (Seuring and Muller, 2008). Therefore, we adopted the research protocol and elements suggested by Dresch et al. (2015) to organize the systematic literature review process and data collect. These results are explained as follow.

6.3.1 Organization of results

The results of the research protocol adopted are presented in this paper in four macro phases (Mayring, 2002). The first is the material collection, where the material to be collected is defined and delimitated. Furthermore, the unit of analysis, or the selected papers, is defined. Second, in the descriptive analysis, formal aspects of the material are assessed (e.g., the number of publications per year, providing the background for subsequent theoretical analysis). Third, on the category selection, structural dimensions and related analytic categories are selected, which are to be applied to the collected material. Structural dimensions form the major topics of analysis, which are constituted by single analytic categories. Fourth, in the material evaluation, the content is analyzed according to the structural dimensions.

This process should allow identification of relevant issues and interpretation of results. Hence, the related analytic categories selected in this research are: the major contributions and gaps of TRIZ applications in SPSS context, how TRIZ methods have been used for the three categories of PSS (product-oriented, use-oriented and result oriented), the types and context of eco-innovation resulting of application of TRIZ into SPSS, and the most relevant research challenges and research opportunities to advance this topic.

6.3.2 Delimitations and search strategy

The definition of the issue and conceptual framework are as follows: our research aims to understand better how the systematic innovation methods of TRIZ are applied to obtain sustainable innovations during the transition process to SPSS. The research question of this study is: what are the contributions and challenges of the adoption of TRIZ to obtain a fluid transition towards Sustainable PSS? The work team for conduces and review the search process in scientific databases was formed by authors of this study.

The search strategy included the following input data: keywords, period, scientific databases, inclusion/exclusion criteria and eligibility/coding. To determine keywords, and Boolean operators, a preliminary search was performed in Scopus and in the Journal of Cleaner Production. This journal was selected for this study because it has been cited in prior studies as a reference regarding the quality and number of publications on PSS (Reim et al., 2015; Tukker, 2015).

As a result, we identified several keywords cited by literature associated with PSS (PSS, SPSS, product-service system, sustainable product-service system, service economy, servitization, service design, service engineering, product service, dematerialization, system solution, and functional economy). Keywords associated with eco-innovation were identified (innovation, eco-innovation, sustainable innovations, environmental innovation, green innovation, clean innovation and ecology innovation). Keywords associated with TRIZ were also identified (TRIZ, Theory of Inventive Problem Solving, and systematic innovation). The combinations of these keywords were searched for using the following fields: title, abstract and keywords of databases. For example, one of the different combinations of keywords used for this study was: “TRIZ & product-service system & eco-innovation”.

6.3.3 Time range and scientific databases

The period considered for this study was between 1995 and 2015. The objective in cover the past 20 years of research has captured the foundations and the recent developments studies combining PSS and TRIZ disciplines, obtaining a comprehensive analyze. The scientific databases included ProQuest, Scopus (formed by several collections including Web of Science, Inderscience, Emerald, Elsevier, Taylor & Francis, and others) and B-on (formed by 18 collections including Ebsco, IEEE, ISI Proceedings, Sage, Springer and Wiley and others).

Moreover, we also included in the research process the proceedings of main conferences and specific journals regarding systematic innovation and TRIZ (e.g. the International Conference of the European TRIZ Association ETRIA, the MyTRIZ Conference, International Conference on Systematic Innovation, the International Matriz Conference, the International Journal of Systematic Innovation and the TRIZ

Journal). The entire search process reviewed the primary world scientific databases and included more than 35.000 peer-reviewed journals.

6.3.4 Criteria for inclusion and exclusion of studies

For a literature review it is particularly important to define clear boundaries to delimitate the research. In this context, the criteria applied for inclusion and exclusion of studies were defined. The inclusion criteria of studies to perform the systematic review included the following requirements: (i) peer-reviewed papers that were published in English; (ii) scientific studies regarding practical or theoretical evidence on the application of TRIZ for sustainable innovations in PSS or SPSS; (iii) applications of TRIZ in PSS or SPSS combined with other methodologies; and (iv) papers discussing proposed methodologies, methods, models or tools in this topic. The exclusion criteria included the following: (i) studies with high quantitative or statistical bias and (ii) studies with low methodical rigor.

6.3.5 Search process and configurative analysis

Structural dimensions and related analytic categories which allow classification of the reviewed literature can be derived from the deductive or inductive analysis. We follow a deductive process. In a deductive approach, they are selected before the material is analyzed. Along the content analysis, the researcher makes decisions about how the paper is to be comprehended (Seuring and Muller, 2008).

In order to ensure the rigor of results, a strategy indicated is involving two or more researchers when searching for and analyzing the data obtained. In this case, the five authors of paper checked and validate the results. Moreover, during the content analysis process, might be necessary review the structural dimensions and underlying categories complementing the results.

During the process of the search, eligibility, and coding, the first search cycle analyzed approximately 181 titles and article abstracts, and 87 studies were pre-selected for deeper review. After a detailed analytical review, 21 articles were selected. During the reading of the papers made by researchers, the analysis in the most frequent cited references were used as a secondary source of data.

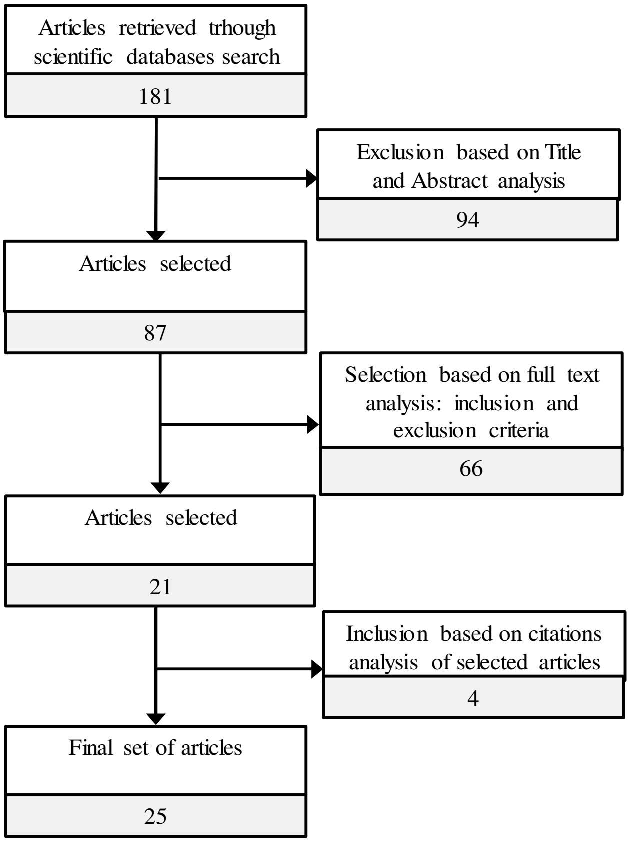

Fig. 1. Systematic literature review selection process.

Then, a second search cycle was conducted analyzing the references of studies that most were frequently cited in the selected papers and adhered to our research goals. In addition, an internet search was conducted to locate any grey literature using a process similar to the database search. This analysis of data yield a reduced number (four papers) of additional papers, which can be taken as an indication of the validity principal search process conducted. The search was finalized and 25 studies were selected for this study.

6.3.6 Rigor of the research process and results

After presenting the primary metadata and descriptive results, a synthesis based on configurative analyses method (Gough, Oliver and Thomas, 2012) is discussed in the following sections. Investigations and the research questions designed to explore a topic more broadly are best answered by means of a configurative review. In this case, the review questions tend to be answered with qualitative data gathered from more heterogeneous primary studies, which are interpreted and explored throughout the review to generate and explore the theory adopting inductive method (Dresch et al., 2015).

The research synthesis by configuration entails the arrangement of thematically diverse individual findings, or sets of aggregated findings, into a consistent theoretical rendering of them (Sandelowski et al. 2012). Thus, the configurative analysis was the method employed to perform the analysis and comparison of the studies ensuring the reliability and robustness of the results obtained in the systematic literary review. Reliability still was addressed by having all steps of the formal analysis conducted by the researchers of this paper. Finally, the results for each topic and section of our study are presented following a similar structure that also was adopted in Vieira and Amaral (2016) published in the Journal of Cleaner Production.

6.4 Results

6.4.1 Descriptive analysis

This section discusses the primary metadata results of the systematic review. Table 1 exemplifies the total of published articles on each topic, and the corresponding matching keywords searched individually in the title of databases. To demonstrate the evolution of the quantity of studies that have been published over the past two decades, we also present an example of the results using the same search criteria (Fig. 2 and 3) from the Scopus database, to avoid duplication of studies between other databases.

Table 1: Examples of search results

Keyword	Scopus	B-on	ProQuest
product-service system	483	700	178
TRIZ	739	3109	408
eco-innovation	212	1145	67

Results indicated an increasing number of published studies regarding these topics and that these topics (Fig. 2) may be considered recent because most of the studies (96%) were concentrated in the last ten years (2005-2015). The number of publications regarding TRIZ incurred a relative reduction only during the final year of the search (2015). Considering the landscape over the past five years (2010-2015), 76% of the studies were published during this time frame (Fig. 3).

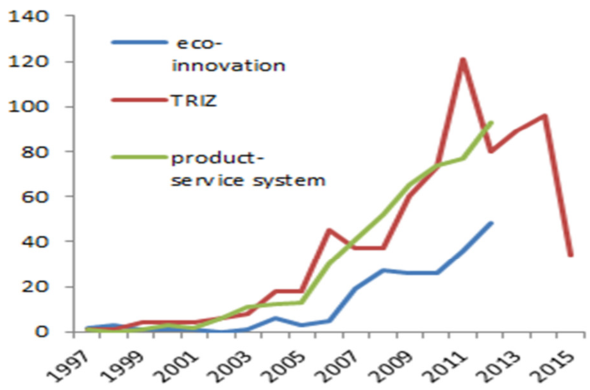

Fig.2. Evolution of the three

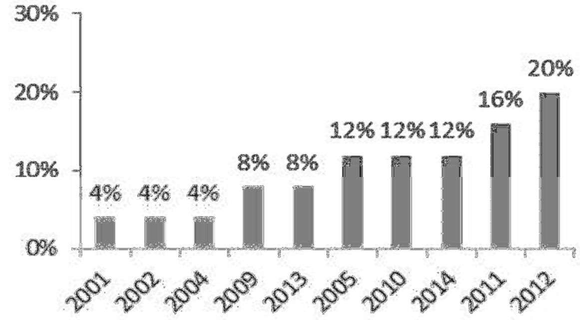

Fig. 3. Selected studies.

Finding 1. There is a growth trend in research on the following individual topics: product-service system, TRIZ, and eco-innovation. The research efforts can be considered recent because the largest number of sample publications was published in the past five years. The rapid growth of these research fields contributes to problems associated with accumulating and systematizing research findings.

Considering only the selected papers resulting from the systematic review (Fig. 3), the results shows have a similar evolution. Approximately 88% of the studies focused on TRIZ + PSS were concentrated in the past ten years (2005-2015), and 68% were concentrated in the previous five years (2010-2015). This concentration of studies suggests that investigations regarding sustainability and environmental innovations based on TRIZ to PSS design have been recently conducted.

Table 2 - **Ranking of institutions**

	Afiliation	%
1	National Cheng Kung University	24%
2	University of Bergamo	12%
3	Northeastern University	8%
4	Sichuan University	8%
5	South-Westphalia University	8%
6	University of South Australia	8%
7	Brunel University	4%
8	Dongguk University	4%
9	Loughborough University	4%
10	Politecnico di Milano	4%
11	Tokyo Metropolitan University	4%
12	National University of Singapore	4%
13	Seoul National University	4%
14	Technische Universität München	4%

Table 3 - **Ranking by country**

	Country	%
1	Taiwan	24%
2	China	16%
3	Italy	16%
4	Germany	12%
5	UK	8%
6	South Korea	8%
7	Australia	8%
8	Singapore	4%
9	Japan	4%

Regards to the studies' countries of origin, 56% were research groups originally from Taiwan, China, and Italy (Table 2 and 3). From a broader perspective, the distribution of studies was as follows: Asia (56%), Europe (36%) and Oceania (8%). Asia was strongly represented by the National Cheng Kung University, Northeastern University and by Sichuan University. These three institutions represented 40% of all publications (Table 2). In Europe, the University of Bergamo was represented by the research group CELS (Research Group on Industrial Engineering, Logistics and Service Operation) and was most representative.

Finding 2. There is a growing trend in studies regarding the integration of PSS, TRIZ, and sustainability. Following the same tendency as individual research on each individual topic, research efforts that integrated TRIZ and sustainable PSS indicate that it is a recent research topic.

Finding 3. Researchers from Asia and Europe published 82% of the research regarding the integration of PSS, TRIZ and sustainability based on environmental innovation.

6.4.1.1 Citations and network of interactions

To enrich the descriptive analyses and comprehend the stat-of-art of this domain, we used the software Publish or Perish (Harzing, 2007) to identify the total quantity of citations that appeared in the selected papers through the systematic review (Table 4). Publish or Perish is a software program that retrieves and analyzes academic citations using Microsoft Academic Search and Google Scholar to obtain, analyze and present metrics regarding raw citations.

The following criteria were used to analyze citations: (i) Total quantity of citations denotes the sum of all citations in all studies; (ii) Average quantity of citations per year denotes the number of citations in the studies divided by the number of years included in the result set. These results were obtained on 25 September 2016. A synthetic description of the area of application of PSS also is presented to better understand the current research framework.

Table 4: Number of citations

Year	Author	Context of PSS	Total number of citations	Average citations per year
2001	Low, M.K, Trond, L., Kathryn, W.	Launderette, telecommunications and car sharing services	52	3.4
2002	Mann, D., Jones, E.	Product-sale of a portable gas turbine powered electrical generator concept	32	2.29
2004	Li-Hsing Shih, et al.	Laptop PSS	21	3
2004	Abdalla et al, A., Bitze, B., Morton, D.	Energy Market in EU (European Energy Exchange in Germany)	12	1
2005	Abdalla A, Bitzer, B., Morton D.	SME sector of machining	12	1.09
2005	Zhao, X.	Theorical proposition	25	2.27
2005	Chai K.H., Zhang. J., Tan, K.C	Leisure resort island and a university	172	15.36
2009	Rovida, E., Bertoni, M., Carulli, M.,	Travelling freely and safely in snowy road conditions using anti-slip devices	13	1.86
2009	Pezzotta, G. et al.	Theorical proposition	0	0
2010	Bao, Z., Zhao, W., Chen, L.	Heavy industry company that developed a hydro turbine axle for a large hydroelectric power plant	1	0.17
2010	Chen, J.L., Li, H. C	Self-service notebook renting station	16	4
2010	Shimomura, Y., Hara, T.	Communication service for HDTV via internet	20	3.33
2011	Pezzotta, G. et al.	Copy printer machine industry	12	2.4
2011	Chen, J.L., Huang, S.C.	Transition of traditional paper books to e-books	1	1
2011	Schrieverhoff et al.	Theorical proposition	1	0.25
2011	Fulea, M.,Brad, S.	Electromechanical SMEs	4	0.8
2012	Kim, S., Park, Y.	Theorical proposition	8	2
2012	Regazzoni, D. et al.	Copy printer machine industry	11	3.67
2012	Kim, S.. Yoon, B.	Car sharing service concept	25	6.25
2012	Chen, J.L., Liu, Y.	Personal computers	1	0,33
2013	Yang, L., Xing, K.	Washing service delivery	3	1
2013	Jie et al.	Agricultural machinery based on computer aided innovation product	2	0.67
2014	Chen, J.L., Jiao, Wei-Su	Office automation furniture	2	1
2014	Yang, L., Xing, K.	Data service system design in a Chinese company	2	1
2014	Fan, H., Sheng, Z	CNC machine tools	1	0.5

Findings show that the study with the largest number of citations (172) and average citations per year (15, 36) was conducted by Chai et al. (2005). This article proposed a TRIZ-based method for a new service design. The studies conducted by Low et al. (2001), Mann and Jones (2002) and Kim and Yoon (2012) were also highlighted by the total of citations. Compared to the other studies, Kim and Yoon (2012), despite being recent paper, had an exceptional average of citations per year (6.25) and may be considered a possible emergent study.

Moreover, a network of interactions (Fig. 4.) was constructed using NodeXL software (Smith et al., 2010) to determine which authors presented in this review were the most cited among the articles included in the analysis. The network was constructed based on the number of citations of the authors presented in the systematic review and of other scholars also presented in the review. Authors without any citations were not considered in the graphic representation, and the number of citations in the selected papers was calculated manually.

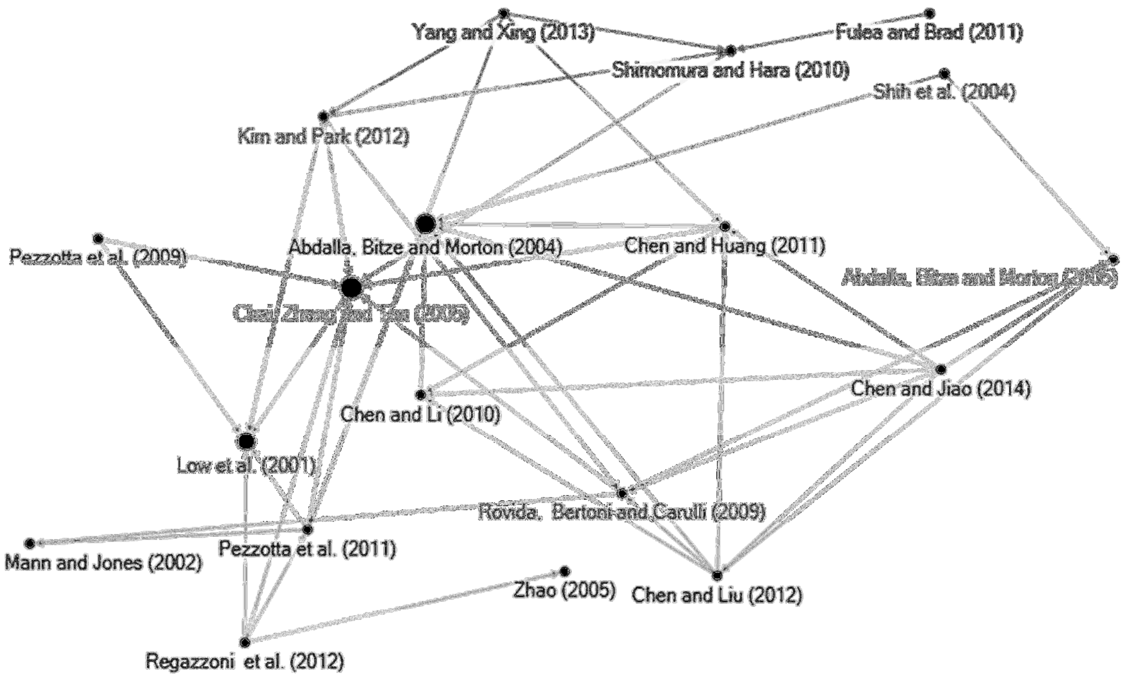

Fig. 4. Network of interactions of literature

The arrows in Fig. 4 point towards the author that was cited. Smaller dots that did not include an arrow represent authors that appeared in the network because they mentioned an author but no one cited them. The primary outcome was that the most cited authors included Abdalla et al. (2004), Low et al. (2001) and Chai et al. (2005). These authors were potential representative authors in this field and may be considered as bottom-line to new studies in this domain.

The network considered only authors that were selected during the systematic review making it possible to affirm that there was no additional information available and suggests that authors of studies cited the most recent articles, considering the time frame available for publishing their work. Furthermore, the network is an effective tool that may be used to identify relevant works and potential principal authors and groups that rely on the same sources of knowledge (Vieira and Amaral, 2016).

Finding 4. The network of interactions and the analyses of citations suggested that potential principal studies include Chai et al. (2005), Abdalla et al. (2004), Low et al. (2001), Mann and Jones (2002) and Kim and Yoon (2012). Chai et al. (2005) published the most cited study globally and between all selected studies.

6.5 Discussion

The critical analysis of the state of the art of the literature presented different contexts about the type, the size of company investigated and business perspective where TRIZ, either isolated or combined with other methodologies, was applied to generate eco-innovation in PSS business models. The case studies discussed in the papers, when a case study was presented, were analyzed and classified in context of application in four primary categories that included services (36%), industrial context (28%), case study on a specific product or problem from a contingency perspective (20%) and theoretical discussion without applying a case study (16%). A detailed discussion follows in the next sections.

6.5.1 Industrial and services context

In the industrial category, discrete manufacturing of consumer goods prevailed and included an SME in the machining sector (Abdalla et al., 2005), a portable gas turbine (Mann and Jones, 2002), a copy printer machine manufacturer (Pezzotta et al. 2011; Regazzoni et al., 2012), electromechanical SMEs (Fulea and Brad, 2011), a heavy industry company that developed a hydro turbine axle (Bao et al., 2010) and the agricultural machinery industry (Jie et al., 2013).

The case studies conducted in the environmental services field were conducted in contexts such as a launderette, telecommunications and car sharing services (Low et al., 2001), a leisure resort on Singapore Sentosa Island and a University (Chai et al., 2005), a study of a self-service notebook renting station (Chen and Li, 2010), services for office automation furniture (Chen and Jiao, 2014), a car sharing service concept (Kim and Park, 2012) and the EU energy market (European Energy Exchange in Germany) in Abdalla et al. (2004).

Other examples in the service context included the following: a virtual washing machine for generating scenarios of washing service delivery (Yang and Xing, 2013), a data service company in China (Yang and Xing, 2014) and a communication service for HDTV via the internet (Shimomura and Hara, 2010). By analyzing several sectors and the context of industrial and services case studies, it was possible to conclude that there was the absence of a dominant orientation (e.g. segment, size of the enterprise, type of product or service, etc) of research efforts in this context integrating the systematic proposal of TRIZ towards service transition.

6.5.2 Contingency cases and theoretical studies

The category of contingency case studies regarding a specific product or problem was heterogeneous. Shih et al. (2009) discussed an eco-innovation method of PSS design of laptops, aiming to reduce the environmental impact along its life cycle. Similarly, Chen and Liu (2012) proposed an eco-innovative low-carbon PSS method and applied the method in a generic case of the physical life of a personal computer. Chen and Huang (2011) presented an eco-innovative design methodology PSS by using functional analysis, the TRIZ substance-field model and a database of 109 PSS cases. The validation of the method was performed regarding a generic discussion of transitioning traditional paper books to e-books. The innovative PSS method in Fan and Sheng (2014) was verified in generic CNC machine tools. Lastly, examples of studies in the category based on a theoretical discussion without practical application may be found in Zhao (2005), Kim and Park (2012) and Pezzota et al. (2009).

6.5.3 Business perspective of studies

Not all case studies had sufficient information regarding the business perspective and about where the research was conducted. However, it was possible to identify the type of business relationships such as B2C (Abdalla et al., 2005; Low et al., 2001; Fulea and Brad, 2011; Yang and Xing, 2013) and B2B (Pezzota et al., 2011; Regazzoni et al., 2012; Kim and Yoon, 2012; Shih et al., 2009; Bao et al., 2010). No study regarding the B2G perspective was verified or emerged for future research opportunities. In regards to the size of the enterprise investigated, only few studies clearly reported this aspect. For example, Abdalla et al. (2005) analyzed an SME of the machining sector in the US and Fulea and Brad (2011) analyzed electromechanical SMEs.

Finding 5. Considering the miscellaneous context of studies that included PSS, segment, size, product type, and business perspective, there was no research regarding sustainable innovations using TRIZ in SPSS. This outcome allows stated relevant aspects. First, in order to achieve more maturity in this research field, it is necessary for future research to include a larger number of case studies. Second, propose rigorous research to understand certain contingences, such as type of PSS, segment, size or business perspective, are also opportunities for advance. Third, a comparison of the results of eco-innovations developed between the three types of PSS may also be a necessary direction for new studies.

Finding 6. The findings also showed that there was no study that included the use of TRIZ and PSS in the B2G context. Therefore, this topic emerges as an opportunity for future research to this type of company.

6.5.4 Major contributions from literature

After the contextualization of the existing research, we deepened the analysis aimed at understanding how TRIZ is used in SPSS design. It was possible to classify (Table 5) the artifacts in alignment with the category of PSS by Mont (2002) as follows: type 1 (product-oriented PSS), type 2 (use-oriented PSS) and type 3 (result-oriented PSS). Aiming understand better the rigor of theoretical contributions to PSS domain, the studies were also classified into the types of artifacts according to classification of Design Science Research approach (March and Smith, 1995) as follows: constructs, models, methods or instantiations.

According to Dresch et al. (2015), constructs or concepts form the vocabulary of the domain and constitute the conceptualization used to describe problems within the domain and to specify solutions. Constructs and concepts form the specialized language and shared knowledge of the discipline or sub-discipline. Constructs are extremely important in natural and design science. Constructs and concepts define the terms used when describing and thinking about tasks. A model is a set of propositions or statements among constructs that expresses relationships and is a representation of how things are. A method is a set of steps used to perform a task.

And instantiation can be defined as the realization of an artifact in its environment. In others words, instantiations operationalize constructs, models, and methods.

We found that 48% of the studies could classified such as product-oriented PSS, composed by 28% classified as models and 20% categorized as methods. 16% of studies were classified as being use-oriented PSS and models. And 20% of studies were classified result-oriented PSS, in which 12% of artifact were classified as methods, 4% were classified as models and 4% were classified as instantiation. For the remaining studies (16%) information was lacking regarding the PSS type or included simultaneous PSS categories in the same study. The major contributions including the classification of types of PSS and the types of artifacts according to design science research are detailed (Table 5).

Table 5: Major contributions on TRIZ in SPSS

Major contributions with TRIZ in SPSS	**Artifact type**	**PSS type***
Carrying sustainability to future systems, products and services requires the availability of sustainability awareness starting from the design and development phases. This paper provides an example of implementing this concept through presenting a PSS development strategy through the development of a Simulation Product Service of Material and Energy Flow in Production Facilities based in TRIZ. (Abdalla et al., 2005).	Model	1
Presents a model based in TRIZ to generation of innovative environmentally friendly solutions in PSS. (Low et al., 2001).	Model	2
To describes the application of the TRIZ-based systematic innovation process to an exemplar Sustainable Service Systems case study. (Mann and Jones, 2002).	Model	1
Describes an integrated model with DMAIC and TRIZ for product and process creativity and innovation and how TRIZ integrated into Six Sigma will accelerate new product or services introduction and ensures a profitable life cycle. (Zhao, 2005).	Model	i
Proposes a concept generation method for service-supporting product development from the service-centric point of view. TRIZ is applied to generate PSS concepts because it is a systematic problem solving methodology and it can effectively resolve the contradictions in a PSS design (Kim and Park, 2012).	Method	1
Propose a way to use the Laws of Technical Systems Evolution (LTSE) and the Evolution Trends of TRIZ to predict what are the most likely improvements that can be made to a given PSS (Pezzotta et al., 2011).	Model	1
A new approach to traditional service design integrating TRIZ system modelling and problem-solving tools to propose a new TRIZ based approach to cover the weakness in service design. (Regazzoni et al., 2012).	Model	1
Demonstrates the viability of applying the TRIZ to services by proposing a new method to identify, generate, and evaluate possible solutions to	Method	3

service problems. (Chai et al., 2005).		
A TRIZ based eco-innovative design methodology to support designers to develop PSS. (Chen and Li, 2010).	Model	2
To understand how the TRIZ may be applied in PSS. How can industrial designers and engineers be supported by systematic innovation techniques when developing both the "hard" and "soft" part of a product-service combination. (Rovida et al., 2009)	Model	1
An eco-innovative design method for developing eco-leasing type product service systems using TRIZ method. (Chen and Jiao, 2014).	Model	2
A novel approach to creating promising PSS concepts by resolving contradictions between product and service components based in TRIZ. (Kim and Yoon, 2012).	Method	1,2,3
Look into the applicability of TRIZ in PSS. (Abdalla et al., 2004).	Model	3
Proposes a two-phase integrated PSS Design And Evaluation (PSSDAE) approach by integrating new tools and procedures; users could generate idea and concept generation, design factors determination and supporting system design. (Shih et al., 2009).	Method	1
The novelty introduced with this paper consists in the integrated use of TRIZ Laws of Technical System Evolution to assess a PSS evolution level in order to better understand as-is scenarios and to support predicting future potential evolutions. (Pezzotta et al., 2009).	Proposition	i
Presents an eco-innovative design methodology to support designers in developing product service systems (PSS) by using functional analysis and the TRIZ substance-field model (Chen and Huang, 2011).	Method	3
Proposes a TRIZ-based method to facilitate innovative concept generation for PSS development. (Yang and Xing, 2013).	Method	3
Proposes a low-carbon emission concept PSS innovative design method and an assessment to assist the designer developing clear concepts of low-carbon effective PSS. (Chen and Liu, 2012)	Method	1
A new concept innovation model for Product Service Systems (PSS) development. The method consists of structured processes for concept generation and concept evaluation, and is constructed by employing TRIZ, QFD, and fuzzy methodologies. (Yang and Xing, 2014).	Model	2
The approach aims at an early integration of resource and environmental requirements into the innovation process and consists of three phases: Target identification, target synthesis and target attainment.(Schrieverhoff et al., 2011).	Method	i
An approach to support creativity, collaboration and tacit knowledge exploitation while designing successful software-PSS. (Fulea and Brad, 2011).	Instantiatio n	3
An innovative product design process for service and logistics. Through analyzing the user's demand for products exploring services data of user's demands, the service information framework based on knowledge frame system was built up. (Bao et al., 2010).	Model	1
A TRIZ based method is proposed to enable service designers to identify existing conflicts in design solutions and to develop basic strategies to solve them. (Shimomura and Hara, 2010).	Method	1
An integration method of QFD and TRIZ centred on acquisition and analysis of the customer's need and its transmission and distribution to PSS design. (Fan and Sheng, 2014).	Method	1
A new PSS design method was proposed by applying function stimulations	Method	1

such as function collaboration, function supplement, and function displacement. (Jiet et al., 2013).	

* Caption on PSS type: 1 (product-oriented PSS), 2 (use-oriented PSS) and 3 (result-oriented PSS) and i (without enough information on the PSS type)

Table 5 summarizes a comprehensive description of main contributions of selected studies. This synthesis represents the entire list of papers reviewed, providing an essential understanding on the topic. A few systematic methods evolving TRIZ was identified. Method is the most systematic and structured category of artifacts, because they are organized by definition in step by step stages to perform a task. Due to this fact, methods have more practical contribution to the companies systematically to develop PSS business models. Therefore, systematic methods minimize the research gaps associated with the “lack of knowledge within firms” (Vezzoli et al., 2015, p. 8). They are especially necessary for teams with little formal engineering background or teams which have to go beyond their professional experience by using elements of TRIZ scope (Fresner et al., 2010, p.128).

In this case, results from literature shows that TRIZ is applied mainly to generate PSS concepts for service-supporting product development (Kim and Park, 2012; Shih et al., 2009; Shimomura and Hara, 2010; Yang and Xing, 2013), to identify, generate and evaluate solutions (Chai et al., 2005) and to create PSS concepts in the three types of PSS (Kim and Yoon, 2012). Moreover, a particular category of eco-efficient oriented methods (Chen and Liu, 2012; Schrieverhoff et al., 2011) and models (Chen and Li, 2010; Chen and Jiao, 2014) was identified between the contributions to this research field.

Finding 7. Results indicated that 84% of the studies involving TRIZ could be classified according to PSS classification by Mont (2002) and according to types of artifact Design Science as Dresch et al. (2015) in the following categories: 48% were product-oriented PSS (28% were models and 20% were methods), 16% were models of use-oriented PSS and 20% were result-oriented PSS (12% were methods, 4% were models and 4% were instantiations). Findings from PSS literature claim that systematic and structured methods are a current research gap and, therefore, are a type of artifact particularly necessary. This occurs because they may be more effective to support systemic innovation (Ceschin, 2013; Omann, 2003) and to solve contradictions and incoherencies (Barquet et al., 2016) during the servitization process. Finally, only a few systematic methods evolving TRIZ in SPSS are available in the literature and more studies that propose methods are needed.

6.5.5 Systematic and sustainable innovations

The interrelationship between the results obtained and the sustainable development applying TRIZ along PSS transition revealed interesting outcomes. These findings corroborated the advantages of TRIZ in solve contradictions and systematically generate eco-innovations increasing the potential of cleaner production practices. In this sense, according to Kemp and Foxon (2007), the eco-innovations are classified into the following categories: environmental technologies, organizational innovation for the environment, product and service innovation and green system innovations.

Environmental technologies are technologies associated with pollution control, clean production processes, waste management equipment, environmental monitoring and instrumentation, green power technologies, water supply and noise or vibration control. The organizational innovation for the environment are organizational methods and management systems designed to address environmental issues in products and production such as more efficient processes, environmental management, audit systems and management of the value chain.

Product and service innovations are new products/services or environmentally improved products and environmentally beneficial services such as solid and hazardous waste management services, water management, environmental consultancy, engineering and testing and analyses services And green system innovations can be defined as alternative systems of production and consumption that involve a set of changes in production technologies, knowledge, organization, institutions and infra-structures and possibly, changes in consumer behaviour. Lastly, general purpose technologies possess certain configurations and types of environmental uses such as biotechnology and TICs.

Initially, based on Kemp and Foxon's (2007) classification, it was possible to affirm that all new methods found in the systematic review (see Table 5) that integrated TRIZ into PSS applied to a company that sought eco-innovations, could be classified as organizational innovation for the environment in the context of this company (e.g., Chen and Jiao, 2014; Chen and Liu, 2012; Yang and Xing, 2013). Eco-innovation classified as green system innovation was noted in Chen and Huang

(2011). In Chen and Huang (2011), the resultant environmental idea was to use a new technology (a solar battery instead of a traditional battery) to reduce pollution in the transition of traditional paper books to e-books. In Fulea and Brad (2011), the organizational eco-innovations used were TICs based in software to successful PSS design, such as an innovation toolbox based on the implementation of tools such as House of Quality and certain TRIZ tools, such as an open innovation module based on PSS and an expert module to suggest innovation projects based.

Environmental technologies and eco-innovations of a simulated PSS that included material and energy and how environmental technologies flow in production facilities also were identified (Abdalla et al., 2005). Product and service innovation was the most frequent type of eco-innovation identified in approximately 80% of the studies available in the literature.

Several examples of service eco-innovations in PSS resulting from the adoption of TRIZ were identified. Such as for example, is highlighted a low-carbon PSS evolving personal computer that changed from “recycling parts”, “providing parts” and “replacing broken parts” to “contract recycled parts” and “provide new and good parts” (Chen and Liu, 2012) and a case study of office automation furniture (Chen and Jiao, 2014). Shimomura and Hara (2010) discussed a new on-demand communication service for a specific type of HDTV that was provided by a Japanese manufacturer. Other service innovation examples included a virtual washing machine for customer generated scenarios of washing service delivery (Yang and Xing, 2013).

Yang and Xing (2013) analyzed scenarios of a washing service delivery to a PSS, and three systematic eco-innovations were generated: one, washing machines were deployed in the customer’s residence and operated by this customer only; second, a clean clothes supply service and third, a mobile laundromat. Service-oriented eco-innovation obtained by a systematic way also included, a self-service notebook renting station (Chen and Li, 2010), a copy printer machine (Pezzota et al., 2011; Regazzoni et al., 2012) and services such as launderettes, telecommunications and car sharing services (Low et al., 2001).

Furthermore, product eco-innovations were identified. Such as for example, a computer aided agricultural machinery in Jie et al. (2013) and a heavy industry company that developed a hydro turbine axle for a large hydroelectric power plant (Bao, Zhao and Chen, 2010). Studies integrating product-service eco-innovations were noted in a laptop PSS business model case (Shih et al., 2009) and in a case that developed, produced and sold anti-slip devices (e.g., snow-chains and snow tires) with service add-ons (e.g., installation and repairs) in Rovida et al. (2009).

Finding 8. Considering that 80% of eco-innovations resulting in the application of TRIZ in PSS were classified as typical products or service eco-innovations based in Kemp and Foxon (2007) classification, we identified the opportunity to explore the systematic TRIZ tools in others eco-innovation categories. Therefore, studies that applied the systematic TRIZ tools to obtain eco-innovations classified as environmental technologies and green system innovations by Kemp and Foxon (2007) are suggested. Finally, based on discussion of results the main evidences and challenges to the diffusion of adoption of systematic proposed of TRIZ in SPSS business models are analyzed in next section.

6.6 Research Challenges Towards Systematic SPSS

Despite advantages of systematic proposal of TRIZ, the analyses based on the outcomes from literature review allow concluded that, the research regarding the integration of sustainable PSS and TRIZ methodology is far from being a mature discipline in the PSS field. Findings show that several new research challenges need be addressed in order to obtain an efficient integration of TRIZ methodology through the SPSS design, leveraging the potential cleaner production. In order to advance in this direction, the main challenges and evidences from the literature are presented and discussed in this section in the most prominent analytic categories.

6.6.1 Reference Artifacts

There are no still established methodologies, methods or even reference models that have been developed that have become either a standard artifact accept between the academic community and professionals evolving in the studies regarding servitization. In the same manner, although the method proposed by Chai et al. (2005) has an significant number of citations and average citations per year, it is possible affirm that the same statement about the absence of reference models to servitization also is valid in relation to methods and reference models on TRIZ approach.

Therefore, as a result, in the same manner as occur in PSS field, there is no yet in the literature a standard artifact accepts between the academic community and professionals evolving the integration between TRIZ and PSS. Moreover, findings suggest that a common understanding on all possibilities and applications areas to systematically develop PSS business models with TRIZ is not yet available in the literature. Due to the absence of a reference artifact, the most part of the literature discussed the integration of TRIZ and PSS, or also evolving engineering artifacts as the QFD (Fan and Sheng, 2014; Kim and Park, 2012; Kim and Yoon, 2012) and others recognized tools.

6.6.2 Novelty of Topic

Probably the more relevant challenges to improve the diffusion of TRIZ methodology are related with the diffusion of this discipline. The research efforts discussing TRIZ in PSS are recent and the largest number of publications was published in the past five years. In this early research stage of scientific contributions, a negative effect to be avoided by academics is related with the fact of the rapid growth of these research fields contributes to problems associated with accumulating and systematizing research findings.

Recently Reim et al. (2015) corroborate stating that there is an increased need to synthesize the findings of existing studies, providing directions for future research on the important topics of PSS business models and tactics. This aspect has occurred because the rapid growth of the researches in PSS, may contribute to problems associated with accumulating and systematizing of stock of knowledge and research findings. Results from literature still show that research groups from Asia and Europe published the most part of the studies in this emergent topic, investigating the integration of PSS, TRIZ and environmental innovation issues.

Hence, a relevant challenge oriented to the novelty of this topic is to improve the diffusion in other research communities in service field and regions, in order to obtain a more systematic look to the development of SPSS business models. And a start point in this direction, considering all research communities evolving in the wide service field, is “avoid citation syndicates” (Boehm and Thomas, 2013, p. 255).

6.6.3 Research Orientation and Contingency

Results from studies carried out in industrial and services show that there is no a dominant direction of research efforts. Thus, in this context, a research challenge to scholars is to include a larger number of case studies in their investigations looking for patterns of results. Our findings also reinforce the hypotheses that systematic and structured methods are more effective to support systemic innovation and more investigations oriented to propose pragmatic methods are necessary. The advantage obtained from this direction is in the fact of improving the internalization of TRIZ an SPSS within the organizational processes of the companies. Particularly, this aspect is valid for small and medium-sized enterprises that, in general, are characterized by lack of competences and organizational learning in sustainable innovation issues (Pacheco et al., 2017; Klewitz and Hansen 2014; Triguero et al., 2013).

6.6.4 Terminology and Typology

A common and accept terminology between scholars to the studies on the development of integrated solutions adopting TRIZ and SPSS is not yet available on literature. Results show that there is an overlapping of meaning among terms use in both topics. Nonetheless, there available in literature on PSS field some propositions of typologies (Ostaeyen et al., 2013; Park et al., 2012) that can offer insights in the direction of a development of a common typology on the integration SPSS and TRIZ methodologies.

According to Park et al. (2012) there is no a standard systematic framework that can accommodate various the PSS concepts. They define the term, “integrated product–service” (IPS), comprising eight related concepts. Ostaeyen et al. (2013) proposed a novel PSS typology adopting functional hierarchy modelling and based on the level of integration and the performance orientation of the dominant revenue mechanism within the PSS. Therefore, a common terminology and taxonomy to this domain is necessary in order to contribute with the diffusion between research communities and practitioners.

6.6.5 Ranking of Publications

Some publications have been published in high-ranking journals originally from Services field, such as the Journal of Service Research (Chai et al., 2005), the journal Service Business (Kim and Yoon, 2012), CIRP Annals - Manufacturing Technology (Shimomura and Hara, 2010) and others. This aspect denotes the acceptance of this topic by editorials in relevant journals of service field. On the other hand, due to the novelty of this field, the most of publications reporting new developments and ideas integrating TRIZ in SPSS are mainly available in conference of product-service system community, such as for example, the CIRP conference proceedings. Hence, outcomes reveal that there is a research challenge to increase the publications in well recognize journals on environmental and innovations issues.

6.6.6 Methods and Tools

Findings demonstrate that there is an evident collection of research efforts in order to develop structured and step-by-step methods combining only recognize TRIZ tools (e.g. IPs and Contradiction Matrix). These studies propose solving contradictions and generate eco-innovations along the macro phases of literature in PSS design (Regazzoni et al, 2012; Low et al., 2001) or so they emphasize the conceptual design phase (Kim and Park, 2012; Rovida et al., 2009; Chai et al., 2005). Nevertheless, considering the existence of studies on contingency cases and theoretical investigations, a more comprehensive framework of applications in real cases is necessary in order to identify the most suited methods and TRIZ tools according to the phase of SPSS life cycle. This challenge is particularly necessary to define the systematic methods/tools, beyond IPs and Contradiction Matrix, which are efficient on environmental issues according to SPSS life cycle.

6.6.7 Industrial and Service practice

Results evidenced that the practical application of both disciplines in industry and in service context is scarce due the reduced amount of empirical applications demonstrated by literature. Only a few of the existing investigations classified as empirical researches report detailed practical implications. Hence, the diffusion of practical applications and case studies with wide sample of cases studies in both industrial and service related context, are a research opportunity to the integration of both methodologies.

6.6.8 Frequent Tools and Implementation

The most part of studies integrating TRIZ in SPSS exploring the use of well-established TRIZ, as for example the 40 Inventive Principles and the Contradiction Matrix. They are considered classical TRIZ tools. Despite of significant potential and results obtained by application of these tools (Kim and Park, 2012; Yang and Xing, 2014), several others systematic-oriented of TRIZ scope tools may be explored by scholars.

Therefore, the first challenge regarding discussion on systematic tools is extend and consolidate the discussion on others TRIZ tools. Such as for example, the 9 Windows tool, Ideal Final Result and Ideality, 76 Standard Solutions, and Smart Little People. Corroborating this assumption, Fresner et al. (2010) found that especially the concept of the Ideal Final Result, and the Laws of Evolution form a conceptual framework which can aid effectively in the identification of improvement options in cleaner productions activities in a systematic manner. Finally, the literature also suggests that in some cases arise some difficulties to the companies accept some TRIZ tools without the support of experts in the methodology. Therefore, the challenge to overcome this barrier remains and may impact on the diffusion of TRIZ during in the SPSS development.

6.6.9 Life Cycle and System Elements of PSS

Results from literature review demonstrate that integrate and comprehensive artifact able to encompass all the different system elements of PSS design process (e.g. actors, entities, stakeholders) is missing, even if a few appropriate studies have been generate in this direction. As consequence, is possible affirm that a multi-disciplinary orientation is one of the core aspects for embracing and integrating the different perspectives of the PSS offer (Cavalieri and Pezzotta, 2012). A relevant contribution of our results in a life cycle perspective of PSS is evidence that this research field is still in an early stage from the perspective of lifecycle analysis of sustainability in PSS design. As a result, several definitional elements are still under development, and there are research opportunities in order to advance in a more systematic PSS business models.

6.6.10 Impact on the Sustainability and on the Cleaner Production

The confluence of global economic and environmental crisis that has occurred in recent years has consolidated the understanding of the interdependence between our economic and environmental systems and provided a new impetus to international efforts to promote the transition towards more sustainable industrial systems and green industry. This has required the broadening of the definition of cleaner production to include resource efficiency which is a key element of the transitions towards green industry and green economy (UNEP, 2017).

Aligned with these previous assumptions, Fresner et al. (2010) found that the eight TRIZ Laws of Evolution of Technical Systems defined by Genrich Altshuller have similarities and correspondence with the strategies of Cleaner Production. The eight laws of evolution of technical systems are: (i) Stages of evolution of a technological system, (ii) Evolution toward increased ideality, (iii) Non-uniform development of system elements, (iv) Evolution toward increased dynamism and controllability, (v) Increased complexity followed by simplification, (vi) Matching and mismatching elements, (vii) Evolution toward micro-level and increased use of fields, (viii) Evolution toward decreased human involvement. And the main strategies of Cleaner Production are: New raw materials, Changes in operational, practices, Internal and External recycling, Technology change, and Product redesign. Yang and Chen (2011) also found correspondence between the seven eco-friendly elements of World Business Council For Sustainable Development (WBCSD) and the engineering parameters of contradiction matrix and the Laws of Evolution of Technical Systems.

In this sense, results from our systematic review (Chen and Liu, 2012; Chen and Huang, 2011; Pezzota et al.; 2011; Regazzoni et al., 2012 and others) shows that some of these several similarities (Fresner et al., 2010; Yang and Chen, 2011) yet are not totally explored by literature applying TRIZ in SPSS. Some examples of these potential similarities are discussed. The ‘stages of evolution of a technological system’ and ‘new raw materials strategy’ are correspondence with: acquiring material safety data sheets, evaluating them, and using them in supply chain management. The law ‘increase in complexity and decrease again’ and ‘external recycling’ are similar regarding to: waste separation, replaced by application for mixed waste (yarns for carpets, plastic for fuel). The ‘Increasing ideality law’ and ‘product redesign’ cleaner strategies are correspondence with: avoid harmful materials, longer life materials/product. Lastly, ‘increase in dynamics and control’ and ‘technology change’ cleaner strategy are synergic with: counter current flow, cascaded use, energy efficient systems. In short, the innovative principles and evolution patterns of the TRIZ method can systematically enhance the design level of new products/services achieving resulting in eco-innovations. Thus, considering the similarities able to be explored between the TRIZ Laws of Evolution of Technical with the strategies of Cleaner Production, the challenge to scholars in PSS field is incorporate this affinity in SPSS design process.

To concluded, our major findings indicated that the systematic innovation proposed by TRIZ is a promising research field into PSS design able to enable more SPSS business models, filling several research gaps regarding the servitization process. The primary contribution of our work is in covering the past two decades provides a comprehensive critical review of foundations and recent developments in a specific topic within the PSS field: the integration of systematic TRIZ methodology in the design of SPSS business models.

As a result, our investigation also fills important gaps highlighted by previous literature. These research gaps claim the lack of support to a more systemic innovation in service-oriented business (Ceschin, 2013; Omann, 2003), the need of solve contradictions and incoherencies (Barquet et al., 2016), and the lack of appropriate supporting methods/tools for companies engaging in servitization (Vasantha et al., 2015; Beuren et al., 2013; Vasantha et al., 2012). Thus, a particular contribution of this study is establishing directions about how TRIZ can be applied in the SPSS design to achieve effective service-oriented value offers. In this point, the scientific value added of this work extends the current literature by providing important insights and main challenges in SPSS applying TRIZ.

On the whole, the several findings and insights generated along this study propose a structured aggregation of knowledge and understanding of tactics integrating both disciplines. Challenges to obtaining a more synergic diffusion of both approaches were highlighted and can serve as the bottom line to new advances towards systematic SPSS. Finally, our results may support professionals and scholars to successfully design and implement SPSS business models resulting in economic and environmental benefits. The next section provides the conclusions, limitations and research agenda to advance in this emergent field.

6.7 Conclusions and Research Directions

A primary reason for advocating for the adoption of SPSS solutions is dealing with the current unsustainable patterns of consumption, contributing to reducing consumption through alternative scenarios of product use, with closing material cycles, increasing overall resource productivity and dematerialisation. Nevertheless, developing and implementing SPSS which are successful and positively impact sustainable development continues to be a challenge for companies. Prior studies have demonstrated that the primary barriers to this diffusion are related mainly with

(i) user acceptance and adoption, (ii) the resolution of contradictions and incoherencies during this transition (e.g., trade-offs between different sustainability targets arise during servitization), (iii) lack of appropriate supporting methods and tools for companies and (iv) a need to support systemic innovation in enterprises.

TRIZ is worldwide recognized by the potential in solve contradictions and leverage the innovation capacity. Traditionally in management, contradictions are resolved using compromising solutions. However, TRIZ is intended to eliminate such commitments. This perspective allows the generation of solutions that are needed to create changes or solutions based on the application of radical scientific discoveries when the use of traditional engineering and management practices can no longer produce sufficient results (Nakagawa, 2011).

This research investigated how TRIZ has been applied in the servitization process to achieve effective SPSS. We identified that the stock of knowledge available to support how enterprises and practitioners may adopt TRIZ in this context are still very limited and several research opportunities are promising in this research field. The descriptive analysis demonstrated the growing trend of publications in last five years and illustrated the ranking of publications by country and by University. Researchers from Asia and Europe published approximately 82% of the studies regarding this topic.

Most of the studies analyzed are B2C and B2B businesses and no study was found that analyzed the B2G perspective. Regarding the size of enterprises (SME or large), only a small number of studies clarified this aspect. Considering the diversity of the contexts (type of PSS, segment, size, product type, and business perspective), we identified a lack of dominant orientation in studies regarding this field.

This work also included certain limitations that should be considered. Although our search process included the main scientific databases and collections (e.g., Scopus, Web of Science, B-on, ProQuest, and TRIZ Conferences and TRIZ Journals) totalling more than 35.000 peer-reviewed journals, other sources such as private university databases or a deep look in none indexed literature were not considered. Also, in our research protocol, only peer-reviewed papers that were published in English were selected. Studies that were published in other languages could be analyzed. Our study may be complemented with other categories of analysis and perspectives on this topic. Although there are limitations, this study identified insights that could be analyzed in future works contributing and expanding the discussion regarding the adoption of systematic and structured artifacts to obtain a fluid transition to SPSS.

On the whole, several are the challenges for the scientific community working specifically in this research topic or in PSS field. Based on gaps in the literature that were identified during a systematic review, our results suggest that relevant research opportunities exist in order to achieve more success in systematically implementing Sustainable Product-Service Systems in different segments of enterprises, business areas and, particulally, in SMEs.

First, the rapid growth in this domain from an individual perspective of disciplines (e.g., PSS, SPSS, TRIZ and eco-innovation) may help solve problems associated with accumulating and systematizing findings. There is a growing trend in studies regarding the integration between SPSS and TRIZ. Hence, investigations oriented to develop constructs or typologies to define concepts on these topics are needed. The goal is to avoid problems associated with accumulating and systematizing of findings (Reim et al., 2015).

Second, our results demonstrated that the proposition of new methods is a relevant and necessary step to advance towards effective SPSS business models, allying sustainable innovations and reduction in environmental impacts. Therefore, opportunities for future studies include extensive testing of current methods that have been identified or perhaps proposing new methods. To expand the adoption of radical eco-innovations (Navas, 2014) with TRIZ in SPSS it is necessary that artifacts have clear and detailed instantiations (Dresch et al., 2015). Detailed instantiations, particularly within new and well organized TRIZ methods, are specially recommended. Studies defining rules and assessment of the quality and consistency of instantiations of artifacts regarding this topic also are suggested for future studies.

Third, considering the diverse context of studies, our results indicated the lack of a dominant direction in this topic. For this field to become more mature there is a pressing need for future studies that involve a larger number of case studies. Fourth, other research opportunities include contingences and context. Our results demonstrated the lack a dominant research direction of a current topic, there is a need for rigorous analysis to understand certain contingences (e.g., types of PSS, segment, size or business perspective of enterprises). Fifth, future studies could compare the results of eco-innovations between the three categories of PSS (product-oriented, use-oriented and result-oriented).

Sixth, no study regarding the use of TRIZ and PSS in the B2G context was identified in the literature, indicating a possible opportunity for future studies. Seventh, scholars from Asia and Europe published approximately 82% of the studies regarding this topic. Therefore, numerous research opportunities for academic and practitioners of PSS and TRIZ exist for other regions of world, such as Africa, Latin America. Eighth, approximately 80% of the eco-innovations resulting in PSS may be classified as product or service eco-innovations. Therefore, future studies could apply TRIZ tools to obtain environmental technologies, green system innovations and eco-innovations.

Finally, “Because of the potential of SPSS to deliver social well-being and economic prosperity while operating within the limits of our planet, the research community has been inspired to analyse cases in diverse sectors, to increase the understanding of the potential benefits, drivers and barriers, and to develop and to test methods and tools to be able to enhance the array of SPSS that are implemented globally. This is urgently needed because, despite all the knowledge and experience that has been accumulated, there remain gaps in the research as well as a significant gap in how all this knowledge is transferred to implementation” (Vezzoli et al. 2015, p. 3). In alignment with this statement, we then conclude that TRIZ has great potential to be an important alternative and enabler to obtain more effectiveness in Systematic and Sustainable Product-Service Systems (SSPSS) design. This research may be used as a reference font for future research interested in the application of the TRIZ methodology in the development of SPSS business models.

Acknowledgments

This research was supported by the Portuguese Foundation for Science and Technology (FCT) and the Brazilian Council for Scientific and Technological Development (CAPES/CNPq) under grant number 230916.

REFERENCES

Abdalla, A., Bitzer, B., Morton, D. 2004. Benchmarking TRIZ in the field of product service systems PSS, In: Proceedings of the 4th ETRIA TRIZ Future Conference, Florence, Italy.

Abdalla, A., Bitzer, B., Morton, D. 2005. Innovation management methods and tools for sustainable product service systems (With a Case Study). TRIZ Journal, April.

Almeida, C.M.V.B., Agostinho, F., Huisingh, D., Giannetti, B.F. 2017. Cleaner Production towards a sustainable transition. Journal of Cleaner Production 142, 1-7.

Altshuller, G. 1999. The innovation algorithm: TRIZ, systematic innovation, and technical creativity. Worchester, Massachusetts: Technical Innovation Center. 312 p.

Altshuller, G. 2004. And Suddenly the Inventor Appeared. edited by S. Shulyak, Lev; Rodman. Worcester, MA: Technical Innovation Center, Inc..

Baines, T., Lightfoot, H., Benedettini, O., Kay, J. 2009. The servitization of manufacturing: a review of the literature and reflection on future challenges, Journal of Technology Management, 20 (5), 547-567.

Bao, Z., Zhao, W., Chen, L. 2010. Research on Innovative Product Design for Service and Logistics. In: Proceedings International Conference of Logistics Engineering and Management (ICLEM), Chengdu, China, 575-583.

Barquet, A. P., Seidel, J., Seliger, G., Kohl, H. 2016. Sustainability factors for PSS business models. Procedia CIRP 47, 436 – 441.

Becker, J., Beverungen, D., Matzner, M., Müller, O., Pöppelbu, J. 2011. Design Science in Service Research: A Framework-Based Review of IT Artifacts in Germany. In: Proceedings of 6th International Conference, DESRIST. USA.

Bereketli, I, Genevois, M. E. 2014. An integrated QFDE approach for identifying improvement strategies in sustainable product development. Journal of Cleaner Production 54 (1), 188–198.

Beuren, F.H., Ferreira, M.G.G., Miguel. P.A.C. 2013. Product–service systems: a literature review on integrated products and services. Journal of Cleaner Production 47, 222-231.

Boehm, M., Thomas, O. 2013. Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. Journal of Cleaner Production 51, 245-260.

Bogatyreva, O., Phal, A.K., Bowter, A., Vincent, J. 2003. Data Gathering for Putting Biology in TRIZ. In: Proceedings of 5th Annual Conference of the Altshuller Institute for TRIZ Studies, Pennsylvania, USA.

Cavalieri, S., Pezzotta, G. 2012. Product–Service Systems Engineering: State of the art and research challenges, Computers in Industry, 63 (4), 278–288.

Ceschin, F. 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production 45, 74-88.

Chai, K. H., Zhang, J., Tan, K. C. 2005. A TRIZ-Based method for new service design. Journal of Service Research 8, 48-66.

Chechurin, L., Borgianni, Y. 2016. Understanding TRIZ through the review of top cited publications. Computers in Industry 82, 119–134.

Chen, L. J., Jiao, W. S. 2014. TRIZ Innovative Design Method for Eco-leasing Type Product Service Systems. Procedia CIRP 15, 391-394.

Chen, J. L., Liu, Y. 2012. Innovative Design and Assessment of Low-carbon Emission Concept Product Service Systems. In: Proceedings of the 4th CIRP International Conference on Industrial Product Service Systems (IPS2 2012), Tokyo, Japan, 369-374.

Chen, J. L., Huang, S. C. 2011. Eco-Innovative Design of Product Service Systems by using the Substance-Field Analysis Method. In: Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems (IPS2 2011), Braunschweig, Germany, 63-68.

Chen, J. L., Jiao, Wei-Su. 2014. TRIZ Innovative Design Method for Eco-leasing Type Product Service Systems. In: Proceeding of 21st CIRP Conference on Life Cycle Engineering, Procedia CIRP 15, 391 – 394.

Chen, J.L., Li, H. C. 2010. Innovative Design Method of Product Service System by Using Case Study and TRIZ Method. In: Proceedings of the 2nd CIRP international Conference on Industrial Product Service Systems (IPS2 2010), Linköping, Sweden, 299-305.

Chen, J.L., Yang, Y. C. 2011. Eco-Innovation by Integrating Biomimetic with TRIZ Ideality and Evolution Rules. In: Proceedings of 18th CIRP International Conference on Life Cycle Engineering, Braunschweig, Germany, 101-106.

Dahmani, S., Boucher, X., Gourc, D., Marmier, F., Peillona, S. 2014. Towards a reliability diagnosis for servitization decision-making process. Procedia CIRP 16, 259 – 264.

Doualle, B., Medini, K., Boucher, X., Brissaud, D., Laforest, V. 2016. Design of sustainable product-service systems (PSS): towards an incremental stepwise assessment method. Procedia CIRP 48, 152 – 157.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research:A Method for Science and Technology Advancement. Springer. pp.161.

Fan, H., Sheng, Z. 2014.Research on Conceptual Design of Product Service System Oriented on CNC Machine Tools. Advanced Materials Research 889-890, 1471-1480.

Fresner, J., Jantschgi, J., Birkel, S., Barnthaler, J., Krenn, C. 2010. The theory of inventive problem solving (TRIZ) as option generation tool within cleaner production projects. Journal of Cleaner Production 18: 128–136.

Fulea, M., Brad, S. 2011. Ontology-Based Approach for Supporting Creativity in a PSS Design Methodology. In: Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems (IPS2 2011), Braunschweig, Germany, 75-80.

Gough D, Oliver S, Thomas, J. 2012. An Introduction to Systematic Reviews. London: Sage. Publications, 304 p.

Gregor, S., Hevner, A. R. 2013. Positioning and presenting design science research for maximum impact. MIS Quarterly, 37 (2): 337-355.

Halme, M., Jasch, C. M., Charp, M. 2004. Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability. Ecological Economics 51(1-2),125-138.

Harzing, A.W., 2007. Publish or Perish. Available from: http://www.harzing.com/pop.htm.

Hevner, A. R., March, S. T., Park, J., Ram, S. 2004. Design science in information systems MIS Quarterly 28 (1), 75-105.

Hirsch, J.E. 2005. An index to quantify an individual's scientific research output. Proceeding of the National Academy of Sciences of United States of America 102 (46):16569–16572.

Ikovenko S., Bradley, J. 2004. TRIZ as lean thinking tool. In: Proceeding of 4th TRIZ Future Conference, Florence, Italy.

Jie, J., Yan, L., Xiong, Y., Wen-Qiang, L. 2013. Product service systems innovative design based on TRIZ final ideal solutions and function stimulation. Computer Integrated Manufacturing Systems 19 (2), 225-234.

Kemp R, Foxton T. J. 2007. Final report MEI project about measuring ecoinnovation. In: MEI project: measuring Eco-Inovation. European commission. Avaible in http://www.oecd.org/env/consumption-innovation/43960830.pdf. Acess:10/12/15.

Kim, S., Park, Y. 2012. A TRIZ-based Approach to Generation of Service-supporting Product Concepts. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering 6 (2), 487-490.

Kim, S., Yoon, B. 2012. Developing a process of concept generation for new product-service systems: a QFD and TRIZ-based approach. Service Business 6, 323–348.

Kjaer, L.M., Pagoropoulos, A., Schmidt, J. H., McAloone, T.C.2016. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. Journal of Cleaner Production 120, 95-104.

Klewitz J, Hansen EG (2014) Sustainability-oriented innovation of SMEs: a systematic review. Journal of Cleaner Production 65 (15), 57-75.

Kubota, F. I., Rosa, L. C. 2013. Identification and conception of cleaner production opportunities with the Theory of Inventive Problem Solving. Journal of Cleaner Production 47, 199–210.

Lelah, A., Boucher, X., Moreau, V., Zwolinski, P. 2014. Scenarios as a tool for transition towards sustainable PSS. In: Proceedings of 6th CIRP International conference on Industrial Product-Service Systems, 122-127.

Liberati, A. et al. 2009. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. PLoS Medicine, 6 (7), 1-27.

Lin, C.C., Lin, H.H., Huang, K.C. 2016. TRIZ Retrospect and Prospect. IEEE Proceedings: The 2016 3rd International Conference on Systems and Informatics (ICSAI 2016), 1072-1076.

Li, N., Jiang, Z. 2013. Modeling and optimization of a product-service system with additional service capacity and impatient customers. Computers & Operations Research 40 (8), 1923–1937.

Low, M. K., Trond, L., Kathryn, W., Odd, M. 2001. Manufacturing a green service: engaging the TRIZ model of innovation. IEEE Trans Electron Packag Manuf. 24 (1), 10–17.

Mann, D., Jones, E. 2002. Sustainable Services & Systems (3s) through systematic innovation methods. The Journal of Sustainable Product Design. 2 (3), 131-139.

March, S. T. and Smith, G. F. 1995. Design and natural science research on information technology. Decision Support Systems 15 (4), 251-266.

Mayring, P. Introduction to qualitative social research.Weinheim, Germany: Beltz Verlag; 2002.

Maxwell, D., Vorst, van der R. 2003. Developing sustainable products and services. Journal of Cleaner Production 11, 883–895.

Meredith, J. 1993. Theory building through conceptual methods. International Journal of Operations & Production Management 13 (5),3–11.

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

Moussa, F.Z.B., Rasovska, I., Dubois, S., Guio, R., Benmoussa, R. 2017. Reviewing the use of the theory of inventive problem solving (TRIZ) in green supply chain problems, Journal of Cleaner Production, 142 (4), 2677–2692.

Nakagawa, T. 2011. USIT: A New Paradigm for Creative Problem Solving - It´s Concept and Usage. In: Proceeding of 7th TRIZ Symposium, Japan TRIZ Society, NPO. Yokohama, Japan.

Navas, H.V.G. 2014. In: Garrido SA, Brandenburg M, Carvalho H, Cruz-Machado V. Eco-Innovation and the Development of Business Models. Ed. Springer International Publishing., 314 p.

Navas, H. V. G. 2013. TRIZ: design problem solving with systematic innovation. In: Denis AC (ed) Advances in industrial design engineering. Rijeka, Croatia, InTech, 75–97.

OECD. 2009. Sustainable manufacturing and eco-innovation: Framework, Practices and Measurement. Synthesis Report Paris: OECD. Available in: http://www.oecd.org/dataoecd/15/58/43423689.pdf

Omann, I. 2003. Product-service systems and their impacts on sustainable development – a multi-criteria evaluation for Austrian companies. Frontiers, 1-34.

Pacheco, D.A.J, ten Caten, C.S., Jung, C. F., Ribeiro, J. L. D., Navas, H. V. G. , Cruz-Machado, V. A. 2017. Eco-innovation determinants in manufacturing SMEs: Systematic review and research directions. Journal of Cleaner Production, 142 (4), 2277–2287.

Paiola, M., Gebauer, H., Edvardsson, B. 2012.Service Business Development in Small-to Medium-Sized Equipment Manufacturers. Journal of Business-to-Business Marketing 19 (1), 33-66.

Pezzotta, G., Regazzoni, D., Cavalieri, S., Rizzi, C. 2009. A TRIZ-based approach for Product-Service Engineering. In: Proceedings of Quaderni della XV Summer School Impianti Industriali Meccanici - Sustainable Development: The Role of Industrial Engineering, Monopoli, Italy.

Pezzotta, G., Regazzoni, D., Cavalieri, S., Rizzi, C. 2011. Enhancement in Industrial PSS Design based on TRIZ: a Case Study. In: 3th CIRP International Conference on Industrial Product Service Systems, Braunschweig, Germany, 225-230.

Qu, M., Yu, S., Chen, D., Chu, J., Tian, B. 2016. State-of-the-art of design, evaluation, and operation methodologies in product service systems. Computers in Industry 77, 1-14.

Regazzoni, D., Pezzotta, G., Persico, S., Cavalieri, S., Rizzi, C. 2012. Integrazione di strumenti TRIZ nel processo di ingegnerizzazione di un product service system. In: Proceedings of 2nd Congresso Nazionale Del Coordinamento Della Meccanica Italiana, Ancona, Italy.

Regazzoni, D., Pezzotta, G., Persico, S., Cavalieri, S., Rizzi, C. 2012. Integration of TRIZ problem solving tools in a product-service engineering process. In: Proceedings of 4th CIRP International Conference on Industrial Product-Service Systems, Tokio, Japan, 399-404.

Reim, W., Parida, V., Ortqvist, D. 2015. Product e Service Systems (PSS) business models and tactics e a systematic literature review. Journal of Cleaner Production 97, 61-75.

Rennings, K. 2000. Redefining innovation - Eco-innovation research and the contribution from ecological economics. Ecological Economics 32 (2), 319-332.

Rovida, E., Bertoni, M., Carulli, M. 2009. About the use of TRIZ for product-service development. In: Proceedings of 17th International Conference on Engineering Design - ICED, Stanford, USA, 133-145.

Russo, D., Regazzoni, D., Montecchi, T. 2011. Eco-design with TRIZ laws of evolution. In: ETRIA World TRIZ Future Conference 9, 311-322.

Russo, D., Rizzi, C., Montelisciani, G. 2014. Inventive guidelines for a TRIZ-based eco-design matrix. Journal of Cleaner Production 76, 95-105.

Salazar, C., Lelah, A., Brissaud, D. 2015. Eco-designing Product Service Systems by degrading functions while maintaining user satisfaction. Journal of Cleaner Production 87 (15), 452–462.

Sandelowski, M., et al. (2012). Mapping the mixed methods - mixed research synthesis Terrain. J Mix Method Res Author Manuscript, 6(4), 317–331.

Savransky, S. D. 2001. Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving. CRC Press, Boca Raton New York, 1st Ed. 394 p.

Schrieverhoff, P., Jørgensen, R., Kubach, M., Köglmeier, M., Lindemann, U., Möller, K., Faulstich, M. 2011. Resource and Cost Oriented Innovation Steering in Sustainable Product Design. In: Proceedings of EcoDesign 2011: 7th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Kyoto, Japan, 660-663.

Seuring, S., Muller, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production 16,1699–1710.

Shih, Li-Hsing., Chen, J.L., Tu, Jui-Che., Kuo, Tsai-Chi., Hu, A. H., Lin, Sheng-Lung. 2009. An integrated approach for product service system development: I. Design phase. J. Environ. Eng. Manage. 19 (6), 327-342.

Shimomura, Y., Hara, T. 2010. Method for supporting conflict resolution for efficient PSS development. CIRP Annals - Manufacturing Technology 59, 191–194.

Smith, M., Ceni, A., Milic-Frayling, N., Shneiderman, B., Mendes Rodrigues, E., Leskovec, J., Dunne, C., 2010. NodeXL: a free and open network overview, discovery and exploration add-in for Excel 2007/2010/2013/2016. http://nodexl.codeplex.com/ from the Social Media Research Foundation. http://www.smrfoundation.org.

Spreafico, C., Russo, D.2016.TRIZ industrial case studies: a critical survey, Procedia CIRP 39:51–56.

Storbacka, K., Windahl, C., Nenonen, S., & Salonen, A. (2013). Solution business models: Transformation along four continua. Industrial Marketing Management, 42(5), 705–716.

Tranfield, D., Denyer, D. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Triguero, A., Moreno-Mond, L., Davia, M.A. 2013. Drivers of different types of eco-innovation in European SMEs. Ecological Economics 92, 25-33.

Tukker, A. 2015. Product services for a resource-efficient and circular economy - A review. Journal of Cleaner Production 97, 76-91.

Tukker, A. 2004. Eight types of Product-Service System: Eight ways to sustainability? Experiences from SusProNet. Bus. Strategy Environ. 13, 246–260.

Tukker, A., Tischner, U. 2006. Product-services as a research field: past, present and future reflections from a decade of research. Journal of Cleaner Production 14, 1552-1556.

UNEP (2017). Available in: http://www.unep.fr/scp/cp/

Vasantha, G.V.A., Roy, R., Corney, J.R. 2015. Advances in Designing Product-Service Systems. J. Indian Inst. Sci. 95, 429-447.

Vasantha, G., Roy, R., Lelah, A., Brissaud, D. 2012. A review of product-service systems design methodologies. Journal of Engineering Design, 23 (9), 635-659.

Venable, J., Pries-Heje, J. Baskerville, R. 2012. A comprehensive framework for evaluation in design science research. In: Proceedings of DESRIST, Las Vegas, NV, 423-438.

Vezzoli, C., Ceschin, F., Diehl, J. C., Kohtala, C. 2015. New design challenges to widely implement 'Sustainable Product–Service Systems. Journal of Cleaner Production 97 (15), 1–12.

Vidal, R., Salmeron, J. L., Mena, A., Chulvi, V. 2015. Fuzzy Cognitive Map-based selection of TRIZ (Theory of Inventive Problem Solving) trends for eco-innovation of ceramic industry products. Journal of Cleaner Production 107 (16), 202–214.

Vieira, L. C., Amaral, F. G. 2016. Barriers and strategies applying Cleaner Production: a systematic review. Journal of Cleaner Production 113, 5-16.

Yang L, Xing K. A. 2014. Concept Innovation Model for Product Service Systems Development and Application. IEEE. Beijing, China.

Yang, C. J., Chen L. J. 2011. Reasoning New Eco-Products by Integrating TRIZ with CBR and Simple LCA Methods. In: Proceedings of 18th CIRP International Conference on Life Cycle Engineering, Braunschweig, Germany, 107-112.

Yang, J. C., Chen, L. J. 2011. Accelerating preliminary eco-innovation design for products that integrates case-based reasoning and TRIZ method. Journal of Cleaner Production 19, 998-1006.

Yang, L., Xing, K. 2013. Innovative Conceptual Design Approach for Product Service System based on TRIZ. IEEE. 247 – 252.

Yoon, B., Kim, S., Rhee, J. 2011. An evaluation method for designing a new product e service system. Expert Syst. Appl. 39 (3), 3100-3108.

Zhao, X. 2005. Integrated TRIZ and Six Sigma Theories for Service/Process Innovation. IEEE. 529-532.

7 Artigo 6: Towards Systematic and Sustainable Product-Service System Design

Abstract

Despite the potential benefits, the diffusion of Sustainable Product-Service Systems (SPSS) is still notably limited. Contradictions and incoherencies appear during the servitization journey affecting the expected benefits and due to this, the gaps in the literature highlight the need for the adoption of systematic and structured managerial methods and tools to support the implantation. However, efforts to address this debate still have been inconclusive. The Theory of Inventive Problem Solving (TRIZ) is recognized worldwide by potential to solve contradictions and generate innovations systematically. Thus, the main purpose of this study was identifying how the systematic methods and tools of TRIZ could be applied in the transition towards Systematic and Sustainable PSS (SSPSS) contributing to a more efficient and systematic servitization process. A systematic literature review of the past two decades (1995-2016) was conducted based on review protocol. The results of the descriptive analysis suggested the most relevant studies and authors, as well as how the network of relationships between them was detailed. Results also identified which tools and methods of TRIZ are successful applied in PSS, what the main PSS artifacts available are and how the current research framework on this topic is organized. New sustainability oriented strategies and tools and relevant practical contributions to the PSS field were identified. Lastly, a critical analysis was performed, proposing research opportunities and the most prominent key direction of future researches to obtain more systematic diffusion of SPSS. We conclude that TRIZ is an important alternative for enable more effectiveness in SSPSS design. This research can assist PSS practitioners for systematically designing and implementing more PSS business models.

Keywords: Product-Service System. Servitization. TRIZ. Sustainable PSS. PSS. Eco-innovation.

7.1 Introduction

According to Barquet et al. (2016), SPSS business model is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilization and dematerialization, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increasing competitive advantage. However, despite the potential benefits and drivers, the diffusion of SPSS is still limited (Vezzoli et al., 2015).

Nevertheless, the literature shows several results of positive and negative environmental aspects in the servitization process (Barquet et al., 2016; Tukker, 2015; Lelah et al., 2014). The service transformation assumes that PSS may not only reduce the environmental impact but also generate benefits for the PSS provider and consumer in economic and social ways. Given this, why have SPSS not been widely implemented? A possible answer is that sustainability is not an intrinsic characteristic of PSS (Doualle et al., 2016; Pigosso and McAloone, 2016; Tukker, 2015). Contradictions and incoherencies appear during the servitization and can affect the expected benefits. Moreover, more systematic and structured managerial methods and tools must be adopted along with the servitization process (Rondini et al., 2016; Qu et al., 2016; Cavalieri and Pezzotta, 2012) to mitigate the barriers associated with the "lack of knowledge within firms" (Vezzoli et al., 2015, p. 8).

Previous studies also reinforce these findings. According to Omann (2003), the reasons for failure in PSS adoption are associated with the lack of acceptance of consumers and the lack of appropriate supporting methods and tools for enterprises. During the servitization, companies are not properly supported by methods and tools (Rondini et al., 2016). Ceschin (2013) affirms that step-by-step approaches to design, manage and orient the process of introduction and diffusion of eco-efficient PSS are a relevant aspect to mitigate the corporate, cultural and regulatory barriers. "In the transition process toward PSS, manufactures need the assistance of tools, techniques and methods to provide superior service to customers" (Qu et al., 2016, p. 4).

"Simply replacing product selling for service offer might not be enough to lead to more sustainable solutions. Contradictions and incoherencies hinder the potential of PSS business models to provide sustainability benefits and might be a barrier" (Barquet et al., 2016, p. 436-437). Aiming to improve the competitiveness, the inclusion of systematic innovation methods in sustainable design can reduce the innovation risk (Kim and Park, 2012). In sum, additional research is needed to validate or discredit the belief that new services are created as a result of intuition, flair and luck (Menor, Tatikonda and Sampson, 2002).

Therefore, based on the gaps found in the available literature, the adoption of structured and systematic methodologies and tools is necessary to leverage the environmental benefits expected in SPSS design and across its life cycle. In this sense, some recent studies have investigated a promisor framework that applies the systematic methods and tools of the Theory of Inventive Problem Solving (TRIZ) methodology to obtain sustainable innovations and solve contradictions in several research fields (Chechurin and Borgianni, 2016; Chechurin, 2016). TRIZ is recognized worldwide as having the potential to solve contradictions and generate systemic innovations (Navas, 2014; Chechurin, 2016). TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in system design and that aid in problem solving through the elimination or attenuation of the contradictions found (Altshuller, 1999).

Despite the many advantages consolidated by TRIZ demonstrated in the literature on product innovation and technical problem solving (Chechurin and Borgianni, 2016; Ilevbare, Probert and Phaal, 2013), eco-innovation (Vidal et al., 2015), eco-design (Russo, Rizzi and Montelisciani, 2014) and cleaner production (Kubota and Rosa, 2013; Fresner et al., 2010), only a limited number of studies have explored the potential of TRIZ in PSS design. Based in this landscape and in the alignment between the TRIZ proposal and the gaps on PSS literature, we introduced a definition to better comprehend this research field named as Systematic and Sustainable Product-Service System (SSPSS), that can be defined as “an emerging technical discipline focused in the use of systematic and structured methodologies for elimination of the contradictions and generation of systematic innovations along the SPSS development.”

Thus, this paper aims to fill this research gap and contributes by presenting the state of the art of research regarding TRIZ in SPSS. In particular, the research question that this study aims to investigate is “how the methods and tools of TRIZ are applied in the transition process towards SPSS and may contribute to a more efficient and systematic servitization?” The main contribution of our research is that a structured aggregation of knowledge and comprehensive understanding of existent tools, techniques and methods of TRIZ scope applied in PSS design, can assist companies for systematically designing and implementing more PSS business models. A practical significance of our study was identifying several structured strategies, models/methods and tools that can be adopted to trigger the scaling up of SPSSs.

Therefore, a systematic literature review of the past two decades (1995-2016) was conducted following the research protocol by Dresch et al. (2015). The review mainly aimed to answer the following questions on the state of the art of studies regarding the adoption of TRIZ in sustainable PSS design: what are the most cited authors and papers, how is the network of relationship between them organized, which tools, techniques and methods of TRIZ scope are frequently applied in PSS, what are the main PSS artifacts integrating TRIZ, what are the main advances and contributions to the field, and, lastly, what are the research gaps and research opportunities to advance more systematic SPSS design. Section 2 presents the concept of TRIZ, its main tools, techniques and methods, and the SPSS business models. Section 3 details the method and steps of the research protocol that was adopted. Section 4 shows the results, and in section 5, the implications of the results and contributions are discussed. Finally, section 6 presents the study's conclusions, limitations and future research agenda.

7.2 Theoretical Background

7.2.1 What is TRIZ?

TRIZ begun with Genrich Altshuller, working in the Navy patents in his 20s. When analyzing patents in their professional activity, he began to recognize a pattern in the way that problems were solved. Thus, he left his previous work and began to analyze a large number of patents in order to extract their standard troubleshooting so that people could use the method learned to solve problems more creatively (Savransky, 2000).

TRIZ is not based on the spontaneous creativity and intuition of individuals, as the name would suggest. TRIZ is a disruptive technology that demonstrates that the skills to be creative and innovative can be learned (Ikovenko and Bradley, 2004). TRIZ provides the means for problem solvers to access the good solutions obtained by the world's finest inventive minds in any one field of science or engineering (Mann, 2002). Generally, TRIZ's problem solving process is to define a specific problem, formalize it, identify the contradictions, find examples of how others have solved the contradictions or utilized the principles, and finally, apply those general solutions to the particular problem (Navas, 2013; 2014).

TRIZ can be used at different levels (Altsuller, 2004). At the highest level, TRIZ can be seen as a science, a philosophy or a way of being in life (a creative attitude and a permanent search for continuous improvement). At its most practical side, TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in systems, in design and problem solving through the elimination or attenuation of the contradictions found. The process of functional model construction contains the following steps: (i) survey using the available information; (ii) construction of a Substance-Field diagram; (iii) identification of a problematic situation; (iv) choice of a generic/standard solution; and (v) development of a specific solution for the problem.

Traditionally, in management, contradictions are resolved through compromise solutions, while TRIZ is intended to eliminate such a commitment. This concept allows one to generate solutions needed to create changes or solutions based on the application of radical scientific discoveries, where the use of traditional engineering and management practices can no longer produce sufficient results (Nakagawa, 2011).

TRIZ can be applied in several contexts, such as in services, risk management, scientific research, business management, management strategy, analysis of causes, R&D, technology foresight, educational planning, public relations, and advertising (Altshuller, 2004). One advantage of TRIZ over other methods applied to problem solving and innovation is that TRIZ not only helps to identify problems but also offers direct solutions to them with the confidence that most possible new solutions to the problem have been considered (Gadd, 2011).

At the beginning of the process of analysis of a system, there are inconsistencies or contradiction that need to be clarified, and they can be eliminated by modifying the system or one of its subsystems. TRIZ can contribute to accelerating the resolution of problems in eco-innovation activities. The TRIZ analytical tools would be very useful for schematization of eco-innovation tasks, system analysis, identification and formalization of contradictions and problematical situations and their solving processes (Navas, 2014).

7.2.2 Four pillars of TRIZ and the main tools

The four main paradigms that discriminate this methodology from other methods are contradictions, ideality, functionality and the use of resources (Mann, 2002).

7.2.3 Contradictions

A system conflict or contradiction occurs when the improvement of certain attributes results in the deterioration of others. Traditional engineering and design practices can become insufficient and inefficient for the implementation of new scientific principles or for radical improvements of existing systems. The traditional method of technical and design contradiction solving is through the search for a possible compromise between contradicting factors, whereas TRIZ aims to remove contradictions and compromises. The inconsistencies are eliminated by modification of the entire system or by modification of one or more subsystems (Navas, 2014).

7.2.4 Ideality

Ideality is a measure of how close a system is to the best it can possibly be, such as, for example, an ideal service offer. The Law of Ideality states that any technical system tends to reduce costs, reduce energy wastes, reduce space and dimensional requirements, and become more effective, more reliable, and simpler. Any technical system, during its lifetime, tends to become more ideal (Navas, 2014). The Ideality of a system can be expressed in mathematical terms as

$$Ideality = \frac{\sum Benefits}{(\sum Costs + \sum Harms)}$$

The benefits are the useful functions provided by the system. Harms are its unwanted outputs, also regarded as harmful functions of the system. One of the objectives of TRIZ is to increase ideality or move a system toward the IFR. As the above equation indicates, this can be achieved by one or a combination of means of increasing the benefits provided by the system, reducing the costs of resource inputs towards providing those benefits, or reducing the harmful functions or unwanted outputs that come with the benefits (Ilevbare, Probert and Phaal, 2013).

7.2.5 Functionality

Functionality is the idea that a system possesses a main useful function and that any system component that does not contribute towards the achievement is ultimately harmful. Systems may of course perform several additional useful functions according to the requirements of the customer. In traditional functional mapping, the emphasis is very much on the establishment of positive functional relationships between components. TRIZ places more emphasis on both positive and negative relationships of a system and, more importantly, on using the function analysis as a means of identifying the contradictions of the system. Functionality is the common thread by which it becomes possible to share knowledge between widely differing industries. "Solutions change, functions stay the same" is a general message that forms an important thread in TRIZ: people want a hole, not a drill (Mann, 2002).

7.2.6 Use of resources

In TRIZ terms, a resource is anything in the system that is not being used. TRIZ places emphasis on maximization of the use of everything contained within a system and demands an aggressive and seemingly relentless pursuit of things in (and around) a system that are not being used to their maximum potential. TRIZ also demands that the search for resources take due account of negative as well as traditionally positive resources in a system (Mann, 2002).

7.2.7 TRIZ tools

Several tools and techniques have been developed by Altshuller and his research group. The main definitions (Savranksy, 2000; Navas, 2014) regarding them are the following:

Table 1: Main TRIZ tools.

Tool	Definition
40 Inventive Principles (IPs)	Used to obtain conceptual solutions to technical and physical contradictions
76 Standard solutions	Applied to solve system problems without the need of the identification of contradictions. In this case, they are usually applied to correct the undesired interaction between two parts of a system
Separation	Applied to understand and solve physical contradictions and point at solutions

principles	from the inventive principles relevant to the problem.
Contradiction Matrix	A matrix of 39 technical parameters arranged on the vertical and horizontal axes to interact with one another. It is used to point out note the inventive principles that can be applied to solve technical contradictions.
Effects database	A database that includes approximately 2500 concepts extracted from the body of engineering and scientific knowledge and applied to problem solving in several areas.
Patterns of Evolution of Technical Systems	Used to identify directions of technology development. There are eight distinct trends that guide development, and each trend further divides into lines of evolution.
Ideal Final Result and Ideality (IFR)	An arbitrary system that has all its parts performing at the greatest possible capacity, as introduced by Altshuller. The IFR serves as a beacon that guides the achievement of innovative solutions. The Law of Ideality states that any technical system tends to reduce costs, reduce energy wastes, reduce space and dimensional requirements, and become more effective, more reliable and simpler. Any technical system, during its lifetime, tends to become more ideal.
Algorithm for Inventive Problem Solving (ARIZ)	A method composed by several steps utilizing an array of TRIZ tools (some of which are explained above) for finding solutions and innovations. It is reported to be most suitable for difficult and complicated problems.
Function Analysis	Tool applied for understanding the interactions between all the components of the system and to draw out the problems arising from the interactions.
Substance Field Analysis (Su-Field)	Tool similar to function analysis, helping to map out the entire system and point precisely to problems without adding unnecessary details.
9 Windows	Also known as an inventive system thinking or system operator or multi-screen diagram of thinking. It is used to understand the problem or technical system in terms of the context (or environment) in which it exists and the details of the parts within the system itself. It assists in understanding how the problem (its context and details) may change over time, which is useful for the location of solutions.
Analysis of System Resources	The systematic search and analysis of resources within and outside the system to the benefit of the problem situation so that solutions identified are as close as possible to the IFR.
Smart Little People and Size-Time-Cost	Two different creativity tools used to overcome psychological inertia (mental habits that prevent innovation, clarity of thought and thinking outside the box).

7.3 Research Method

A systematic review of the literature provides understanding of the state of the art of the research theme and aids in the identification of information (Dresch et al., 2015; Tranfield and Denyer, 2003; Moher et al., 2009). In this sense, we adopted the research protocol suggested by Dresch et al. (2015) and have detailed the topics as follows. Definition of the issue and conceptual framework: our research aims to comprehend how the systematic innovation methods and tools of TRIZ can be applied to aid to a systematic and structured transition process in SPSS design. The research question of this study is: how can the methods and tools of TRIZ be applied in the transition process toward sustainable PSS, and how might they contribute to a more effective transformation? The work team that performed the systematic review: it was performed by the authors of this study.

Search strategy: keywords, period, databases, inclusion/exclusion criteria and eligibility/coding. For the keyword and Boolean operator's definition, a preliminary search was performed in Scopus, Journal of Cleaner Production and main TRIZ journals (including TRIZ Journal and conference proceedings, e.g., ETRIA Conference). This choice is observed because Scopus is a relevant scientific database and these journals and conferences are cited in previous research studies as references in terms of quality and the number of publications on our research topic.

As a result, we identified keywords associated with our research topics. Keywords associated with PSS include PSS, SPSS, product-service system, sustainable product-service system service economy, servitization, service design, service engineering, product service, dematerialization, system solution, and functional economy. Keywords associated with TRIZ include TRIZ, Theory of Inventive Problem Solving, and systematic innovation. Keywords associated with sustainable innovation include innovation, eco-innovation, sustainable innovation, environmental innovation, green innovation, clean innovation and ecology innovation. Combinations of these keywords were sought in the following fields: title, abstract and keywords of databases. To exemplify, one of several combinations of keywords performed was the following: "TRIZ" & "product-service system" & "eco-innovation."

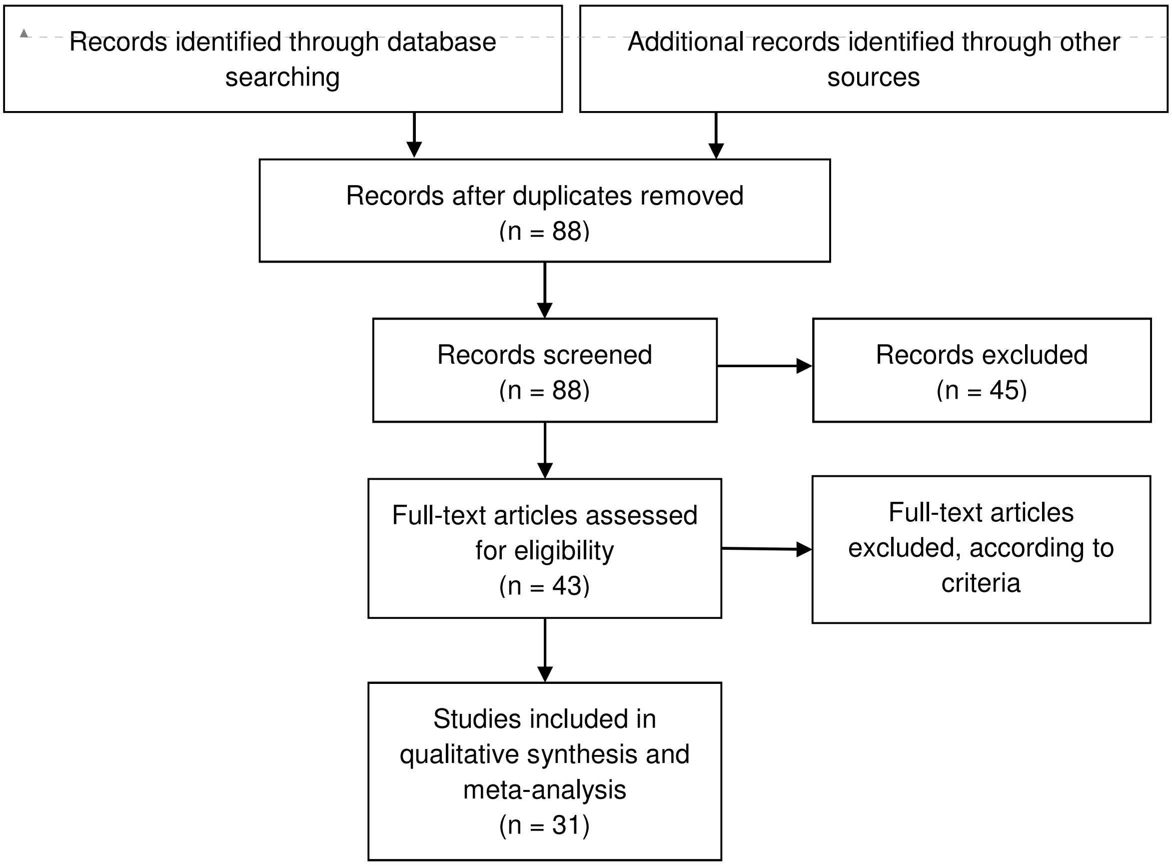

Fig. 1. Synthesis of research protocol.

The search period considered was between January/1995 and June/2016. The selected databases were ProQuest, Scopus (formed by several collections, such as Web of Science, Emerald, Elsevier Inderscience, Taylor & Francis i.e), B-on (formed by 18 collections, including Ebsco, IEEE, ISI Proceedings, Sage, Springer, Wiley i.e) and the proceedings of main conferences and specific journals on systematic innovation and TRIZ (e.g., International Conference of the European TRIZ Association - ETRIA, MyTRIZ Conference, International Conference on Systematic Innovation, International Matriz Conference, International Journal of Systematic Innovation and TRIZ Journal). The full search process covered the primary world scientific databases, totaling more than 35,000 peer-reviewed journals. The research process adopted (Moher et al., 2009) is detailed in Fig. 1.

The eligibility criteria adopted for inclusion of studies during the process review were (i) papers proposing methodologies, methods, models or tools in this topic; (ii) studies on applications of any TRIZ tools in PSS or in SPSS design; (iii) peer-reviewed papers in the English language; (iv) scientific papers demonstrating practical or theoretical evidence on applications of TRIZ in PSS or SPSS; and/or (v) the combination of these methodologies with others approaches. The exclusion criteria adopted were (i) studies with high quantitative or statistical bias; and (ii) studies with low methodical rigor. The search yielded 31 select papers. After presenting the main metadata results and descriptive analyses, the synthesis based on configurative analyses (Gough, Oliver and Thomas, 2012) was considered and is discussed in the next sections.

7.4 Results

7.4.1 Descriptive analysis

This section begins with the main metadata results of the systematic review. We used the software PoP (Publish or Perish) by Harzing (2007) to identify the number of citations that the papers selected in the systematic review had globally (Table 2). PoP is software that retrieves and analyzes academic citations using Microsoft Academic Search and Google Academic, and the main advantage is the inclusion of a number of global citations considering scientific databases and gray literature. The follow criteria were used to analyze the citations: (i) total number of citations: the sum of the citation counts across all papers; and (ii) average number of citations per year: the number of citations of the paper divided by the number of years covered by the result set. These results are the status as of 10 October, 2016. A synthetic description of the area of application of TRIZ tools in PSS is also presented to better comprehend the current research framework.

Table 2: Synthesis of research framework.

#	Authors	Year	Region	Area of application	Total of citations	Citations per year
1	Low et al.	2001	Europe	launderette, telecommunications and car sharing services	52	3,47
2	Mann, D., Jones, E.	2002	Europe	product-sale of a portable gas turbine	33	2,36
3	Zhang, J., Tan, K., and Chai, K.	2003	Asia	improve the car entry system in a family resort island in Singapore	72	5,54
4	Abdalla, A., Bitze, B., Morton, D.	2004	Europe	energy market in EU (European Energy Exchange in Germany	12	1
5	Abdalla A, Bitze B. Morton D.	2005	Europe	SME sector of machining	12	1,09
6	Chai K.H., Zhang. J., Tan, K.C	2005	Asia	leisure resort island and a university.	172	15,64
7	Zhang, J., Chai, K. and Tan, K.	2005	Asia	extension of the hours of operation in university canteens	57	5,18

8	Lin, C., Su, C.	2007	Asia	database software company	50	5,56
9	Rovida, E., Bertoni, M., Carulli, M.,	2009	Europe	travelling freely and safely with snowy road conditions and anti-slip devices	13	1,86
10	Li-Hsing Shih, et al.	2009	Asia	laptop PSS	21	3
11	Pezzotta, G. et al.	2009	Europe	theoretical proposition	0	0
12	Chen, J.L., Li, H. C	2010	Asia	self-service notebook renting station	16	4
13	Shimomura, Y., Hara, T.	2010	Asia	communication service for HDTV via the Internet	20	3,33
14	Pezzotta, G. et al.	2011	Europe	copy printer machine industry	12	2,4
15	Chen, J.L., Huang, S.C.	2011	Asia	transition of traditional paper books to e-books	3	1,5
16	Fulea, M.,Brad, S.	2011	Asia	electromechanical SMEs	4	0,8
17	Kim, S., Park, Y.	2012	Asia	theoretical proposition	9	2,25
18	Regazzoni, D. et al.	2012	Europe	copy printer machine industry	12	4
19	Kim, S.. Yoon, B.	2012	Asia	car sharing service concept	25	6,25
20	Chen, J.L., Liu, Y.	2012	Asia	personal computer	1	0,33
21	Gazem, N., Rahman, A.	2012	Asia	auto repair & service workshop	3	0,75
22	Wu, Y.	2012	Asia	the service design of the offer of dormitories to students by a University	1	0.25
23	Yang, L., Xing, K.	2013	Oceania	washing service delivery	3	1
24	Jie et al.	2013	Asia	agricultural machinery based on a computer-aided innovation product	2	0,67
25	Chen, J.L., Jiao, Wei-Su.	2014	Asia	office automation furniture	3	1,5
26	Yang, L., Xing, K.	2014	Oceania	data service system design in a Chinese company	2	1
27	Fan, H., Sheng, Z	2014	Asia	CNC machine tools	2	0,5
28	Gazem, N., Rahman, A.	2014a	Asia	travel agency	5	2,5
29	Gazem, N., Rahman, A.	2014b	Asia	home-care services to senior citizens or aging-in-place	2	1
30	Chen, C. et al.	2015	Asia	home-care services to senior citizens or aging-in-place	4	4
31	Song, W., Sakao, T.	2016	Asia	leading elevator manufacturer company that provides different types of elevators and associated services	0	0

The study with the higher number of total citations (172) and average citations per year (15.64) is the one by Chai, Zhang and Tan (2005) published in Journal of Service Research. This article proposed a TRIZ-based method for new service design. These same authors also published the studies in second (72) and third (57) place in total number of citations, proposing innovative service design approaches by integrating TRIZ into the conceptual design of service activities in different contexts. Others studies highlighted by the total number of citations are as follows. Low et al. (2001) developed a TRIZ-based model to generate innovative environmental solutions in PSS. Lin and Su (2007) presented a systematic process for creating new services in the service sector based on TRIZ. Considering the citations per year, the recent study by Kim and Yoon (2012) was highlighted with 6.25 citations, which, compared with others papers, is a high number of citations in a small amount of time. On the whole, these papers and authors might be considered for potential studies in this research field.

Considering the regions of studies, we determined that this topic has been investigated mainly in Asia, with 68% of studies being conducted on that continent, while Europe accounts for 26% and Oceania accounts for 6%. Taiwan leads the research in Asia (Fig. 2).

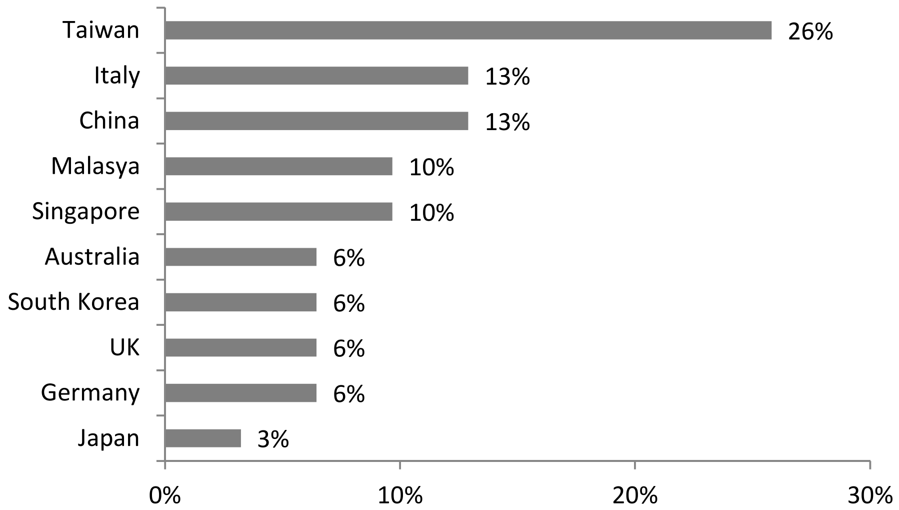

Fig. 2. Ranking by country.

Nevertheless, no paper originated on the African continent or in the Americas, which could be considered opportunities for future research. In Asia, the research studies are divided by several Universities, especially between National Cheng Kung University (19%), National University of Singapore (10%) and Universiti Teknologi Malaysia (10%). In Europe, the research studies on this topic are especially concentered in the University of Bergamo (10%). The same is true in Oceania for the University of South Australia (6%). On the whole, from metadata analysis, we also conclude that it is a young research field because 65% of the papers have been published since 2010.

7.4.2 Network of interactions

A network of interactions was constructed using the NodeXL software (Smith et al., 2010) to find out which authors presented in this review were most cited among the articles analyzed and identify researches network. Thus, the network was constructed based on the number of citations of the authors present in the systematic review by others also present in the review. The counting of the number of citations through the selected papers was conducted manually. The authors without any citations were not considered in the graphic representation (Fig. 3).

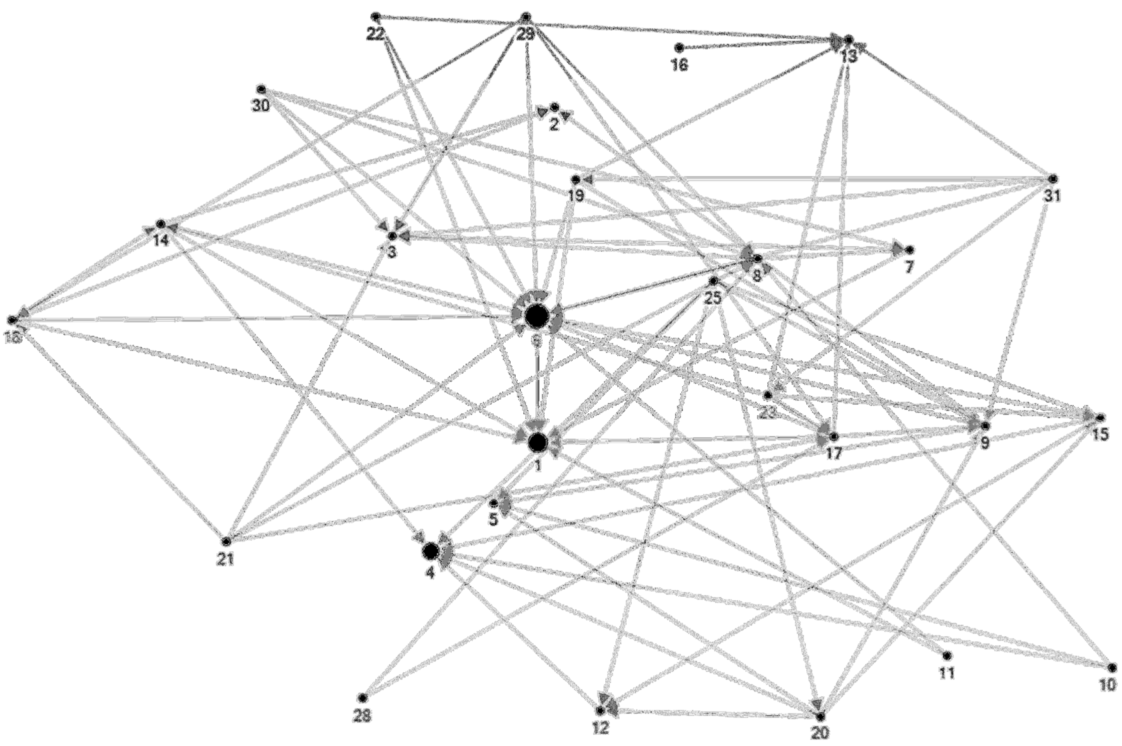

Fig. 3. Network of interactions

The arrows in the figure are pointing towards the author (Table 4) that was cited. Smaller dots that do not have an arrow towards them are from authors that appeared in the network because they cited someone but no one cited them. The outcome is that the most cited authors were Chai, Zhang and Tan (2005), Abdalla, Bitze and Morton (2004) and Low et al. (2001), respectively. We verified that their studies had potential to be the most important in this field. The authors Chai, Zhang and Tan also have the higher number of total citations as identified by the software PoP. In sum, considering analyses of the index of citations and the network of relationships, we can suggest a set of main studies on this research topic (Chai, Zhang and Tan, 2005; Low et al., 2001; Zhang, Tan and Chai, 2003; Kim and Yoon, 2012; Zhang, Chai and Tan, 2005; Lin and Su, 2007; Abdalla, Bitze and Morton, 2004).

Considering the network that takes into account the authors selected in the systematic review, it is possible to affirm that there is nothing to suggest about the possibility of citing the most recent articles, considering the time available for their dissemination. Moreover, the network is an effective tool to identify relevant works, potential principal authors and groups that use the same sources of knowledge (Vieira and Amaral, 2016). The next section discusses the artifacts when applying TRIZ in PSS.

7.5 Discussion

7.5.1 Research framework

After the contextualization of existent research, in this section, we deepen the analysis to understand how TRIZ is used in SPSS design. The theoretical issues and case studies discussed in papers were analyzed carefully to classify them following the categories of PSS according to Mont (2002): type 1 (product-oriented PSS), type 2 (use-oriented PSS) and type 3 (result-oriented PSS).

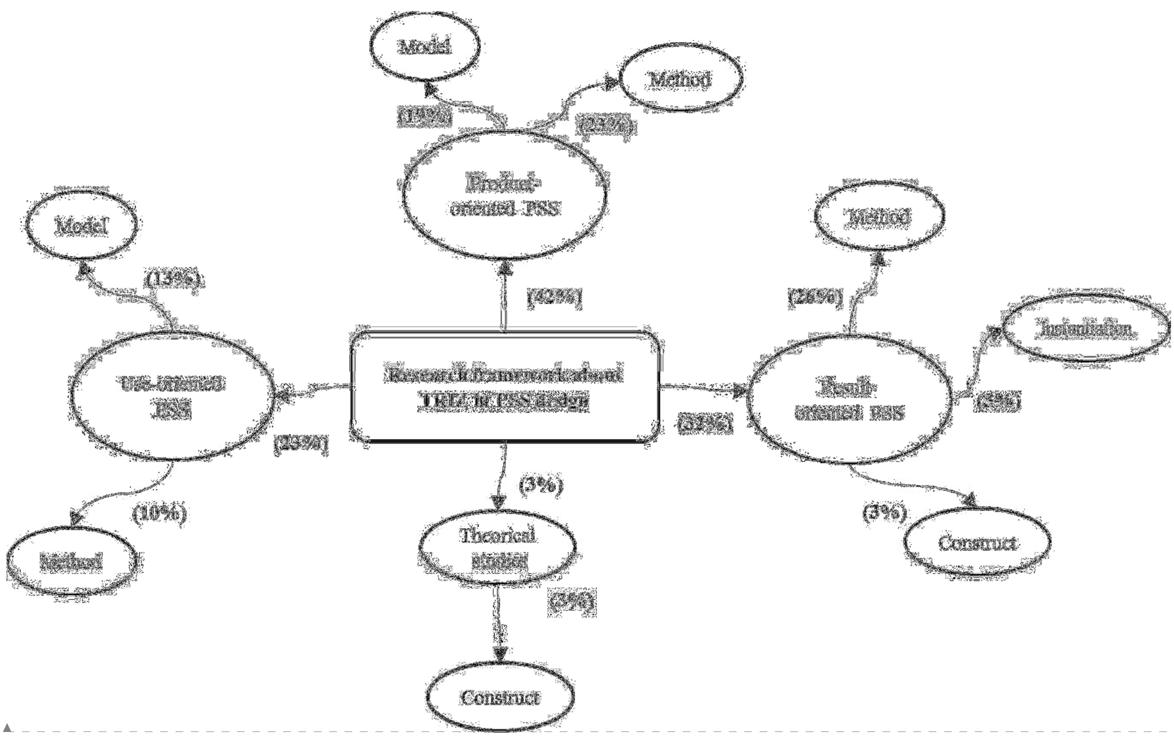

Fig. 4. Conceptual map of the current research framework.

The studies were also classified by types of artifacts in design science (Dresch et al., 2015; March and Smith, 1995): in constructs, models, methods or instantiations. The state of the art of the current research framework regarding the use of TRIZ in PSS design was identified and presented in a conceptual map (Fig. 4).

According to Dresch et al. (2015), constructs or concepts form the vocabulary of the domain. They constitute the conceptualization used to describe problems within the domain and specify their solutions. They form the specialized language and shared knowledge of the discipline or sub-discipline. Constructs are extremely important in design science. They also define the terms used when describing and thinking about tasks. A model is a set of propositions or statements among constructs expressing relationships. It is the representation of how things are. A method is a set of steps used to perform the task. Instantiation is the realization of an artifact in its environment. Instantiations operationalize constructs, models, and methods.

In short, we found that 42% of studies can be classified as product-oriented PSS, of which 19% are classified as models and 23% as methods; 23% of studies are applied in use-oriented PSS, of which 13% are models and 10% are methods; 32% can be classified as result-oriented: 26% methods, 3% construct and 3% instantiation; theoretical studies without case studies were classified as constructs, totaling 3%. The understanding of which TRIZ tools are applied in each type of PSS and artifacts, its convergences and divergences, is made in the discussion of next sections.

7.5.2 Product-oriented PSS artifacts

Abdall, Blitze and Morton (2005) used ARIZ to solve previously identified problems and conduct a scan for the TRIZ tools, looking for new ideas and directions for solutions. To identify the resources available, use the check list of idea generation and IFR. The 40 Inventive Principles are used to produce ideas for solutions. Lastly, solution ideas are generated, usually, by identifying the IFR, finding a contradiction in the system and implementing other TRIZ tools to solve the contradiction, utilizing existing resources, implementing a field and field sensitive substances, and implementing patterns of evolution and the innovative principles to achieve that IFR.

According to Mann and Jones (2002), the Trends of Evolution may be deployed not only in their traditional role as predictors of technological system evolution but also in solving problems associated with the detailed design of system components. A combustor design was matched to the known TRIZ trends to identify in which aspects the design was still at the very beginning of its evolutionary potential. The IFR is used to measure the shift from a product to a use-service market. The Contradiction Matrix is used to solve the conflicts of IFR (e.g., the need to increase the reliability of the system).

Regazzoni et al. (2012) recognized opportunities to adopt TRIZ tools in service engineering processes. To search for and evaluate ideas, functional language can be adopted to create models that highlight criticalities and their eventual interdependencies. Inventive principles and separation principles can be adopted to eliminate contradictions. For requirements analysis: evaluation of the resulting solutions can be conducted by a variety of instruments, including functional descriptions and assessment, inventive principles and separation tools used to solve the contradiction. Trends of Evolution can be used as well to assess eventual enhancements of solutions found, and changes in the degree of ideality are proportional to the quality of solutions. Moreover, market requests may be conflicting, and instead of accepting a compromise solution, contradiction formalism can be used to manage them, and inventive principles can be used to solve them.

In service concepts, to avoid criticalities due to planning issues, inventive principles can be used to overcome proper concept issues that appear. The ideal final result can be a precious means to understand whether the direction of development is correct and to assess the improvement achieved. In the implementation and introduction step, the authors do not envisage the use of any TRIZ tools. For what concerns feedback management, inventive principles can be used for analysis and evaluation, while functional diagrams can support service planning for maintenance. Service provisioning: after the customer has purchased the system, updates and improvements are needed, and a study of evolutionary trends can aid in understanding and implementing solutions to keep systems up to date and competitive towards competitors. In the case that conflicts appear, the inventive principle can be used to eliminate them. At last, Ideality can provide a term of comparison for determining whether we are developing good technical solutions (Regazzoni et al., 2012). The model of Rovida, Bertoni and Carulli (2009) is used to identifying specific product characteristics: Resources, 9-windows matrix (System Operator). To map characteristics problems: Functional Diagrams, to develop the concept of the Contradiction Matrix and Patterns of Evolution to evaluate alternatives and to define concepts, IFR.

In Pezzotta et al. (2011), the Laws of Technical Systems Evolution (LTSE), Evolution Trends and Ideality are used to predict what the most likely improvements that can be made to a given PSS are. As Shih et al. (2009) presented, the Inventive Principles can be used to generate new PSS ideas. The authors also suggest identifying IFR for PSS innovation based on the trend of evolution.

Chen and Liu (2012) build the PSS Su-field model by using information from the results of the system layer analysis map to obtain innovative and improvement low-carbon PSS ideas from standard TRIZ solutions. In the first part of the method, the system layer analysis map is made, and similar PSS cases are found for PSS eco-innovation. Next, the designer can find similar PSS cases in the database. In the second part: find eco-innovation ideas by Su-field analysis building the PSS Su-field model by using information from the results of the system layer analysis map, and one can obtain innovative or improved low-carbon PSS ideas from standard TRIZ solutions. Third part: PSS low-carbon effect assessment: the designer can calculate the PSS low-carbon effect assessment index (PLV and PLCV) to evaluate the effects of the new low-carbon PSS concept.

Shimomura and Hara (2010) proposed a method to enable PSS designers to identify existing conflicts in design solutions and develop basic strategies to solve them. Two different approaches for detecting conflicts were introduced: one entails the use of lexical expressions of functions, and the other involves the ranges of design parameters. The main steps of the method are conflict detection using lexical expressions of functions, conflict detection using the ranges of design parameters and conflict resolution using TRIZ. The method in Fan and Sheng (2014) to solve design problems of PSS has three phases: acquisition and analysis of the customer requirement (questionnaire and analyze by KJ method); transmission and distribution of the customer requirement (AHP to measure importance and transform the customer requirement of PSS into technical characteristics); and analysis and solving of the contradiction among quality characteristics using TRIZ.

Zhang, Chai and Tan (2005) applied TRIZ tools to new service concepts in the field of new service development (NSD). To capture the current situation, an innovative situation questionnaire was used. After, the problem formulator was used to analyze the problem. Based on the rules of using the problem formulator, a set of events was extracted, and the events were linked to each other. A Functional Diagram was developed. Lastly, the contradiction matrix was applied to create solutions and to eliminate contradictions in the case study analyzed.

In Jie et al. (2013), the evolutionary roads to PSS based on TRIZ ideality were provided from a functional perspective to find an optimal balance between physical products and intangible services. The method in Kim and Park (2012) has several steps. In situation analysis, to identify problems, a questionnaire was formulated based on the ISQ (Innovative Situation Questionnaire) of TRIZ. In problem resolution: problems are resolved by applying 40 Inventive Principles modified for the service industry. Solution evaluation: aggregating solutions and identifying contradictions. Concept generation: factors resulting in contradictions are identified as described in the previous step. Next, relevant inventive principles are applied to resolve contradictions. Fan and Sheng (2014) integrated QFD and TRIZ in a detailed PSS method.

Song and Sakao (2016) proposed a method based on the service function and attributes analysis, group decision making with unbalanced linguistic label set and TRIZ methodology. In the step of the Design conflict resolution process, the corresponding TRIZ parameters are identified for the product-service offer technical attributes. After, the TRIZ contradiction matrix is examined to find the corresponding favorable inventive principles. Lastly, following the recommended principles and suggested methods, design experts can perform possible conflict resolutions.

In short, it was possible to conclude that, in the category of product-oriented PSS artifacts of literature, the systematic TRIZ toolkit seems to be similarly applied to execute similar functions. As an outcome, interesting sustainable insights into PSS design were found, e.g., a low-carbon PSS assessment and low-carbon PSS Su-Field model (Chen and Liu, 2012), IPs oriented to services (Kim and Park, 2012) and a checklist for sustainable PSS (Shih et al., 2009).

7.5.3 Use-oriented PSS artifacts

According to Low et al. (2001), the greening of individual products is conducted based on energy, resources and pollution reduction. The parameters found in the Contradiction Matrix are used to generate solutions that address the reduction of such factors. The principles of the resolution of physical contradictions (i.e., separation in time, system structure and parts) may also be employed to drive the innovative process toward the grouping of functions and technologies required during the design of a service.

According Chen and Li (2010), the 40 IPs were original developed for use in engineering and technology domains and are not very suitable for direct application in PSS innovation directly. Therefore, a new definition for each TRIZ inventive principle for PSS innovation was proposed. In Chen and Jiao (2014), the relationship of product characteristic factor level table of eco-leasing and TRIZ parameters was defined to find ideas for the development of new eco-leasing PSS. The authors also proposed two eco-leasing low-carbon effect assessment indexes for SPSS: the eco-leasing low-carbon effect comparison value (ELCV) and low-carbon effect value (ELV) index.

The model of Yang and Xing (2014) has two stages (Concept Generation and Concept Evaluation) and several steps. In Concept Evaluation, QFD is used to map the customer requirements and identify the problems or contradictions that will be solved using the Contradiction Matrix and Invention Principles. It is integrated with decision-making tools (AHP, Fuzzy Logic and Pugh Chart) for concept evaluation and the selection of innovative ideas.

The method of Kim and Yoon (2012) has the following phases. In Customer requirements, the analysis requirements are roughly expressed, depending on natural language that is mainly described by function names and utilities. In service concept generation: QFD, 39 Standard and the Contradiction Matrix are used. From QFD, a transition is made from the sub-service to 39 standards to determine which parameters increase or decrease. Then, a suggested inventive principle in the contradiction matrix is applied to resolve the contradiction. In product concept generation: the Contradiction Matrix is applied, as in resolving contradictions in the service concept generation stage. Each product element is changed to 39 standard technology parameters. After determining which parameters should be increased or decreased through the contradiction matrix, the PSS provider resolves contradictions in the product area and generates a new PSS concept. Finally, the new PSS concepts are evaluated, considering the importance of the problem (QFD). A concept with the highest priority refers to the most important service concept. In evaluation and selection, a new PSS concept is chosen from the concepts.

The method by Lin and Su (2007) has seven steps. First, identify the scope of the problem of service operation by conducting a focus group with customers or consulting the operators of the service. Second, define the IFR of the problem. Third, analyze the contradictions by identifying the conflict points that prevent the acquisition of the ideal solution by applying IPs, physical contradictions, Su-Field, LTSE, IFR, or resources analyses. Fourth, identify the corresponding TRIZ parameters. Fifth, examine the TRIZ contradiction matrix to find the corresponding IPs. Sixth, generate the specific solutions, and lastly, evaluate the feasible solutions. The method in Zhang, Tan and Chai (2003) has five stages. First, perform preliminary problem analysis of the service by applying eight questions. After, problem modeling and formulation: use the problem formulator to build a function diagram by function analysis. Third, contradiction analysis: formulate the inherent contradiction. Fourth, contradiction elimination (ARIZ, IPs and Contradiction Matrix). Lastly, is made solution evaluation with IFR.

In sum, we conclude that, in use-oriented category, QFD or questionnaires are frequently applied to identify customer requirements. The Contradiction Matrix is applied in different stages of artifacts to achieve contradiction elimination during the PSS design or to generate a new PSS concept. Interesting tools developed to obtain more sustainable PSS based on eco-innovations were found. As examples are the new 40 IPs oriented to services and an index system based on 103 PSS cases to explore similarities among PSS to direct eco-innovations (Chen and Li, 2010). Another interesting outcome is the 26 reinterpreted IPs for eco-innovation to PSS design (Yang and Xing, 2014).

7.5.4 Result-oriented PSS artifacts

In Chai, Zhang and Tan (2005), several TRIZ tools are used. In stage 1 of the Problem Definition of an artifact (Situation analysis, Problem modelling, Problem formulation and Result analysis), the following tools are used: Problem Formulator, Tool-Object-Product, Function Modelling and Substance-Field Analysis. In stage 2 of Problem Resolution (Contradiction analysis and Contradiction elimination), the following are used: 40 Inventive Principles, 4 Separation Principles, 76 Standard

Solutions and ARIZ. In stage 3 of Solution Evaluation (Formulate the ideal solution, Prioritize ideas, Formulate local Constraints and Refine ideas), the IFR is applied.

The model of Abdalla, Bitzer and Morton (2004), to define the problems, applies ARIZ to generate ideas by IPs and identify problems by IFR. The patterns of evolution and the Smart Little People method are used to avoid psychological inertia and analyze future scenarios. A Morphological Box is utilized to find the best option from the available resources. S-Curve analysis: PSSs in general are at the beginning of their S-Curves and can be applied in the new developments stage.

The method in Chen and Huang (2011) has three parts. Part 1: use the function analysis tool to analyse one's problem (by building the PSS Su-field model using information from the function analysis results) to obtain innovative ideas from standard TRIZ solutions. Part 2: the first step is to identify the level value of five products' characteristics. Next, the designer can search for the most similar PSS cases from the PSS case database. In the third part: find a sustainable innovation idea from the eco-efficiency vs. service effectiveness table.

Yang and Xing (2013) proposed a TRIZ-QFD method in which the problem solving process of TRIZ is applied with the Contradiction Matrix and IPs. The original TRIZ principles were reinterpreted to suit the characteristics of PSS innovation. Therefore, the better way to apply TRIZ in PSS design is to transform the IPs as well as use the Contradiction Matrix, identifying TRIZ principles to generate a new scenario from the basic scenario. In Fulea and Brad (2011), TRIZ is used as an available innovation methodology, and the tools proposed are: the Contradiction Matrix, Nine Window Analysis, S-Curve, Su-Field, IFR and LTSE. The tools are not applied in a case study. Gazem and Rahman (2014a) provide the interpretation of 40 IPs to the B2C service context using Nvivo software to the support the process, and they group the 40 IPs in a redesign service (Gazem and Rahman, 2014b; 2012) and add in the grouping problem model based on function analyses (Gazem and Rahman, 2012).

Wu (2012) proposed a method with four stages. In the context analysis, interviews with or observations from relevant stakeholders are used. In the problem analysis, the function and behaviors of the customer journey are represented by a map and blueprint. For problem modelling, a problem formulator based on the TRIZ function diagram is developed. Lastly, for problem resolution, 40 IPs and 4 separation principles are used. The model by Chen et al. (2015) starts with the TRIZ model preparation step, in which clients and service-quality needs are delineated by the literature, observation and interview, and next, the service determinants are mapped into the corresponding 39 TRIZ parameters by interviews with managers or staff. In the second step, a service quality survey to assess the determinants of step one is realized with users and staff who provide the services. As a result, the worst service-quality determinants are identified. Third, the TRIZ function-attribute analysis diagram is constructed to detect relationships between negative ("harmful") and positive ("useful") parameters in the service system, and the contradiction matrix is applied to generate IPs for improvements. Lastly, the inventive solutions are generated, evaluated, and prioritized by managers.

On the whole, the analyses of result-oriented PSS artifacts for interesting systematic outcomes were identified, such as the PSS case database and eco-efficiency vs. service effectiveness table (Chen and Huang, 2011). Another insight is that, considering that PSS in general are at the beginning of their S-Curves development, the S-Curve tool integrated with the LTSE and IFR can be a good strategy to systematically achieve value-add propositions for customers and new development stages in SPSS (Yang and Xing, 2013; Abdalla, Bitzer and Mortin, 2004).

Result-oriented are until today the most unconventional PSS and have a large potential for sustainability benefits, since material resources are only a cost factor for the provider and more products produced do not lead to increased revenue (Tukker, 2004; Barquet et al., 2016). Accordingly, considering that only 32% of studies applying TRIZ tools are in result-oriented PSS, there exists the opportunity for more exploratory studies that apply the systematic TRIZ toolkit to leverage the sustainability benefits in this type of PSS.

Finally, the theatrical proposition discussion in Pezzotta et al. (2009) proposes a way to use the LTSE to predict what the most likely improvements that can be made to a given PSS are. The concept of evolution potential allows for comparatively assessing how systems progress towards a predetermined set of evolution steps. The definition of new trends on the base of a recurrent PSS pattern of evolution enlarges the existing set of Trends of Evolution, allowing a proper assessment of PSS.

7.5.5 Rigor of artifacts integrating TRIZ into PSS and contributions

In design science research, there are four main types of artifacts: constructs, models, methods and instantiations (Dresch et al., 2015). Considering the selected studies, we identified the following distribution of artifacts: models (32%), methods (58%), constructs (6%) and instantiations (3%).

According to March and Smith (1995), design scientists often use the term model as a synonym for theory or propose models as weak or incipient theories; propose that phenomena be understood in terms of certain concepts and relationships among them. The concern of models is utility, not truth purposes. In our opinion, models are relevant and initial effort necessary to advance through more systematic and step by step methods in TRIZ into the PSS field. Outcomes showed that approximately only 58% of studies suggested methods to generate innovations with TRIZ in PSS.

A method is set of steps or guidelines to perform the task. In this sense, representations of tasks and results are characteristics intrinsic in methods (March and Smith, 1995). Kim and Park (2012) propose a concept generation method for service-supporting product development from a service-centric point of view. Kim and Yoon (2012) show a method for creating PSS concepts by resolving contradictions between product and service components. A two-phase integrated PSS design and valuation (PSSDAE) method is suggested by Shih et al. (2009). In this method, inventive principles are applied to generate new PSS ideas to identify the ideal final result for PSS innovation based on the trend of evolution. Chen and Liu (2012) proposed a low-carbon emission concept PSS innovative design method and an assessment to assist the designer in developing clear concepts of low-carbon effective PSS. A new PSS design method was proposed by applying function stimulations, such as function collaboration, function supplement and function displacement, in Jie et al. (2013).

In other hand, instantiations are realizations of constructs, models or methods. Instantiations are valuable for demonstrating the utility of artifacts. In addition, they test the feasibility of both the design process and the designed artifact. The utility and feasibility of a method for simulating service processes, for instance, can be demonstrated by a software tool (Becker et al., 2011). In this sense, Fulea and Brad (2011) show a software ontology-based approach for supporting creativity in PSS design based on TRIZ set tools.

Moreover, "[…] instantiations inform the user on how to implement or use a particular artifact and its possible outcomes. Accordingly, instantiations can refer to a particular artifact or the articulation of several artifacts to produce results within a given context. From this logic, it is possible to state that instantiation consists of a coherent set of rules that guide the use of artifacts (constructs, models and methods) in a given real environment" (Dresch et al., 2015, p. 110). Based on this definition, it is possible say that 97% of select studies also have some level or type of instantiations.

However, the critical aspect here is regarding the consistency and clearance of instantiations identified in systematic review to support constructs, models and methods. In this sense, an insight emerges: the need to define a set of rules and criteria to assess the quality and consistency of instantiations developed to the TRIZ+PSS artifacts, and, therefore, new research studies on this subject are highly recommended. For example, were identified studies with clear and detailed instantiations, structured with stages and detailed sub-stages, in only a few studies, which might serve as a bottom line to develop new artifacts (Kim and Park, 2012; Chai, Zhang and Tan, 2005; Chen and Huang, 2011; Yang and Xing, 2013, 2014; Kim and Yoon, 2012, Shih et al., 2009).

In short, regarding the rigor of artifacts, our finds conclude that, to expand the adoption of TRIZ in SPSS, promoting innovation, it is crucial that artifacts have clear and detailed instantiations. This could also help in mitigating one of the main criticisms regarding TRIZ, related to its complexity of execution (Regazzoni et al. 2012; Chai, Zhang and Tan, 2005) and in sustainable PSS design, related to the complex relationships among different social actors involved (Ceschin, 2013; Low et al., 2000; Rovida, Bertoni and Carulli, 2009). Therefore, detailed instantiations, especially inside systematic and structured methods, are an important factor for obtaining success aiming supporting systemic innovation (Ceschin, 2013) and solving contradictions (Barquet et al., 2016) in SPSS designs applying TRIZ. Another finding in this perspective is the need to define specific rules and patterns to evaluate criteria, such as the quality and consistency of instantiations developed in these artifacts.

Another outcome of the systematic review relates to construct and typology. The results showed the need for more research efforts in the development and proposition of constructs and typology aiming to define concepts regarding the integration of concepts of TRIZ and SPSS. This finding is relevant because the rapid growth of the research studies in this field can contribute to problems associated with accumulating and systematizing research findings.

Moreover, to enable more rigorous research studies in this field and facilitate opportunities for new investigations, there is a need to verify if the evaluation criteria of artifacts proposed in the literature in design science research are suitable to evaluate the current TRIZ+SPSS artifacts. In this sense, it is possible to verify if is necessary to develop and validate specific evaluation criteria to assess the efficiency of TRIZ+SPSS artifacts. Research efforts should be made to, in particular, assess the performance criteria of methods due to the great potential to minimize the barriers associated with the lack of knowledge within companies (Vezzoli et al., 2015) and the need that companies have to obtain structured methods that support the PSS design (Ceschin, 2013; Rondini et al., 2016; Qu et al., 2016). In addition, there is the need to structure a hierarchy of these evaluation assessment criteria (Kjaer et al., 2016). The proposals in March and Smith (1995), Hevner et al. (2004), Yoon, Kim and Rhee (2011), Venable et al. (2012) and Gregor and Hevner (2013) may be a bottom line in this agenda.

7.5.6 Systematic methods and tools for PSS design

A detailed content analysis in select studies was performed to identify how TRIZ tools, in isolation or integrated with other methodologies, are applied to SPSS design. The conceptualization, objectives and potential of these tools were previously discussed in section 2. Then, the outcome of the objective perspective of the application along the servitization process of each tool is presented (Table 3).

Table 3: Systematic TRIZ method/tools in PSS design.

TRIZ Tools	Application in PSS
ARIZ	• Solve the previously identified problems and conduct a scan for the TRIZ tools looking for new PSS ideas (Abdalla, Bitzer and Morton, 2005; Chai, Zhang and Tan, 2005). • Identify problems (Abdalla, Bitzer and Morton, 2004).
Ideality and IFR	• To measure the shift from a product to a use-service market (Mann and Jones, 2002). • Understand whether the direction of development is correct and assess the improvement reached in the service concept (Regazzoni et al., 2012; Abdalla, Bitzer and Morton, 2005). • Evaluate alternatives and concepts (Rovida, Bertoni and Carulli, 2009; Chai,

	Zhang and Tan, 2005; Regazzoni et al., 2012). • Identify problems (Abdalla, Bitze and Mortin, 2004) • Evaluate the solution (Abdalla, Bitze and Morton, 2005). • Improve the solutions of concept design (Jie et al., 2013). • Evaluate the solutions generated after eliminating the contradictions (Zhang, Tan and Chai, 2003). • After identify the problem in the service, apply seven questions to identify the IFR (Lin and Su, 2007).
Trends of Evolution and LTSE	• Estimate the value of the system and extend the functionality of the new PSS (Abdalla, Bitze and Morton, 2005). • Predict technological evolution and innovation in PSS stages (Mann and Jones, 2002; Pezzotta et al., 2009; 2011). • Avoid psychological inertia and analyze future PSS scenarios (Abdalla, Bitze and Mortin, 2004) • Solve problems associated with the detailed design of system components (Mann and Jones, 2002) • Develop PSS concepts (Rovida, Bertoni and Carulli, 2009). • Assess enhancements of the solution found and changes in the degree of Ideality (Pezzotta et al., 2009; Regazzoni et al., 2012) • Identify the IFR for PSS innovations based on the trend of evolution (Shih et al., 2009).
Contradiction Matrix	• Generate solutions to reduce the energy, resources and pollution involved (Low et al., 2001). • Solve contradictions in the customer requirements in the QFD (Yang and Xing, 2014) • Problem definition (Chai, Zhang and Tan, 2005) • PSS concept (Kim and Yoon, 2012; Rovida, Bertoni and Carulli, 2009) • IFR (Mann and Jones, 2002). • Solve contradictions and generate solutions in services (Lin and Su, 2007). • Solve conflicts in PSS (Song and Sakao, 2016; Yang and Xing, 2013). • Generate inventive solutions in the service (Chen et al., 2015; Zhang, Chai and Tan, 2005).
Innovation Situation Questionnaire (ISQ)	• Identify problems (Kim and Yoon, 2012). • Obtain situation analysis (Chai, Zhang and Tan, 2005). • Identify the resources that are available (Abdalla, Bitze and Morton, 2005).
Su-Field model	• Find eco-innovation ideas (Chen and Liu, 2012). • Evaluate the evolution stage of the technological system (Abdalla, Bitze and Morton, 2005). • Problem modelling and formulation develop an exhaustive set of problem statements on the basis of the function diagram (Chai, Zhang and Tan, 2005) • Obtain new development stages of PSS (Abdalla, Bitze and Morton, 2004). • Build the PSS Su-Field by using information from function analysis results to obtain innovative ideas from 76 standard solutions (Chen and Huang, 2011).
76 Standard Solutions	• Solve formulated contradictions found in the problem definition (Chai, Zhang and Tan, 2005). • Obtain innovative ideas (Chen and Huang, 2011).
4 Separation Principles	• Define and solve the contradictions between variables (Shimomura and Hara, 2010) and in the requirements analysis of PSS (Regazzoni et al., 2012) • Drive the innovative process toward the grouping of functions and technologies required during the PSS (Low et al., 2001). • Propose solutions to eliminate contradictions in services (Zhang, Chai and Tan,

	2005; Zhang, Tan and Chai, 2003; Wu, 2012).
40 Inventive Principles	• Produce ideas for solution concepts (Abdalla, Bitze and Morton, 2005). • Solve conflicting market requests in service requirements and PSS concepts (Regazzoni et al., 2012). • Analyze and evaluate feedback management (Regazzoni et al., 2012). • Generate new PSS ideas (Shih et al., 2009; Abdalla, Bitze and Morton, 2004) • Solve problems or contradictions of customer requirements in QFD (Yang and Xing, 2014; Fan and Sheng, 2014) • Solve problems or contradictions in problem definition (Chai, Zhang and Tan, 2005; Zhang, Tan and Chai, 2003; Wu, 2012) • Solve problems or contradictions between variables (Shimomura and Hara, 2010). • Reinterpret and redefine concepts to suit PSS innovation (Yang and Xing, 2013; Chen and Li, 2010; Kim and Park, 2012). • Refine the previous grouping of the IPs under five service redesign approaches (Gazem and Rahman, 2012; 2014b). • Interpret the services context (Gazem and Rahman, 2014a).
Resources Analysis	• Extend the functionality of the new PSS (Abdalla, Bitze and Morton, 2005). • Identify the specific product characteristics (Rovida, Bertoni and Carulli, 2009).
9 Windows Matrix	• Identify the specific product characteristics (Rovida, Bertoni and Carulli, 2009).
Smart Little People (SLP)	• Avoid psychological inertia and analyze future scenarios (Abdalla, Bitze and Morton, 2004)
39 Engineering Parameters	• Generalize and solve conflicts (Shimomura and Hara, 2010). • Examine the relationship of products' characteristics to find new ideas for PSS innovation (Chen and Jiao, 2014). • Analyze and abstract each problem to a contradiction containing two engineering parameters, one that should be improved and one that needs to be protected from deterioration (Yang and Xing, 2013). • Determine which parameters increase or decrease in the service/product concept (Kim and Yoon, 2012) • Before solving the conflicts, express the PSS conflict via a standardized description through 39 engineering parameters (Fan and Sheng, 2014). • The requirements of service quality were mapped into the corresponding 39 parameters by interviews with managers, and the parameter correspondence was established afterwards (Chen et al., 2015).
Problem Formulator (PF), Tool-Object-Product, Function Modeling (FM)	• The function diagram is used to represent the interaction between the PSS and the surrounding environment (Rovida, Bertoni and Carulli, 2009) • Problem modeling and formulation develop an exhaustive set of problem statements on the basis of the function diagram (Chai, Zhang and Tan, 2005; Zhang, Tan and Chai, 2003; Wu, 2012). • Detect relationships between harmful and useful parameters in the service system (Chen et al., 2015; Gazem and Rahman, 2012; Lin and Su, 2007). • Use PF and FM to analyze the problem and extract events (Zhang, Chai and Tan, 2005). • A function model of PSS was made based on the service blueprint and functional (collaboration, supplement and displacement) system diagrams (Jie et al., 2013) • FM is used to identify the relationship between different parts of a system. This is performed before Su-field (Chen and Huang, 2011).

By analysis of Table 3, it is possible to identify some relevant outcomes. First, it is possible to conclude that the TRIZ tools are more frequently used. For example, the 40 IPs, when applied individually, and the contradiction matrix are applied to obtain similar objectives in the servitization stages. The 40 IPs are used in most research studies with the goal of solving problems or generating new PSS ideas. In the same manner, Trends of Evolution are used to generate improvements and innovation during the PSS lifecycle.

The second outcome of an analysis of the tools is the recognition that different tools are used to achieve similar objectives. For example, Ideality and IFR are applied to evaluate alternatives and concepts to improve each stage of the process or to improve the solutions of concept design in PSS (Jie et al., 2013; Rovida, Bertoni and Carulli, 2009; Chai, Zhang and Tan, 2005). With a similar objective, a Substance-field is used to develop new stages of PSS (Abdalla, Bitze and Morton, 2004) or obtain innovative ideas (Chen and Huang, 2011). LTSE is generally applied to solve problems (Mann and Jones, 2002) and to predict future technological evolution/innovation in PSS stages (Pezzotta et al., 2009, 2011; Shih et al., 2009). Moreover, from a content analysis of select studies, it was possible to identify and quantify a global ranking expressing the frequency of adoption of TRIZ in PSS design (Fig. 5).

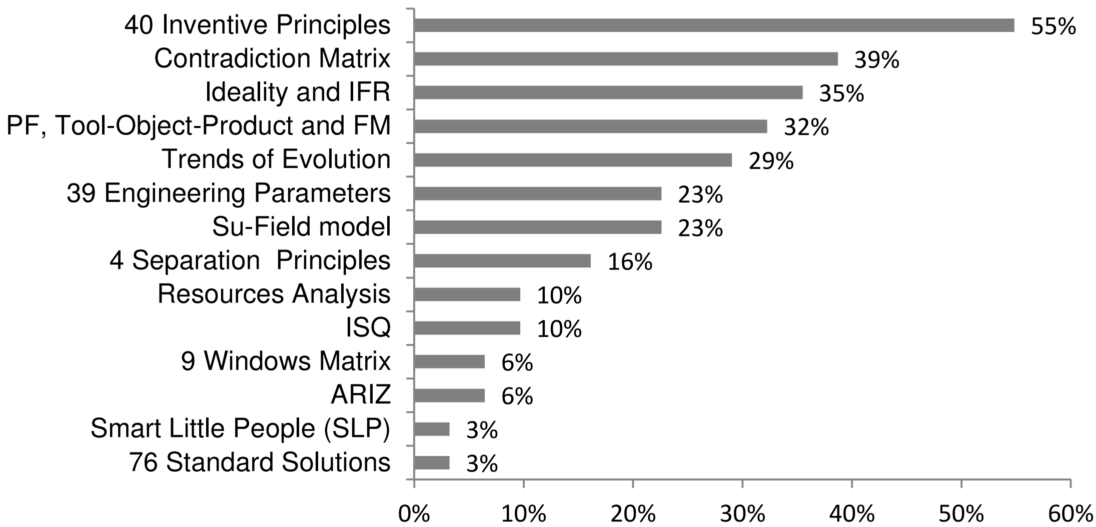

Fig. 5. Ranking of TRIZ tools in PSS.

As a result, it was possible to map not only the TRIZ tools that are most applied in different steps of the servitization process but also the less used tools. It is possible to verify that 55% of studies have used the 40 IPs and 39% have used the Trends of Evolution in some step of PSS design. SLP and other tools are less used. In this sense, the opportunity for new research studies on the less explored tools emerges, such as 76 Standard Solutions, SLP, ARIZ and the 9 Windows Matrix in different steps of the servitization process identifying possible new advances. The same opportunity is valid for others tools of TRIZ scope that were not identified in the literature (Chechurin and Borgianni, 2016).

Moreover, another finding concerns the most frequent combination of tools used in the artifacts. Approximately 85% of studies apply only one or a combination of several TRIZ tools. However, approximately 15% of studies integrated TRIZ with QFD in PSS design. In this case, QFD is used in the conceptual stage of PSS to identify and prioritize the customer requirements and TRIZ helps to eliminate the contradictions in customer requirements (Kim and Yoon, 2012). Studies integrating TRIZ, QFD and quantitative tools (e.g., LCA, AHP, and Fuzzy Logic) were also identified (Shih et al., 2009; Fan and Sheng, 2014).

7.5.7 Major advances and systematic contributions

New and modified TRIZ tools aiming to obtain more systematic PSS and generate environmental innovations during the servitization process were also identified in the literature. From our point of view, these proposals can be highlighted as major advances and contributions of TRIZ towards systematic support of a sustainable servitization process adopting structured tools (Table 4).

Table 4: Major advances and contributions.

Main advances and contributions	Authors
Low-carbon PSS assessment: PSS low-carbon effect value (PLV), PSS low-carbon effect comparison value (PLCV) and low-carbon PSS Su-Field model.	Chen and Liu (2012)
IPs were reinterpreted and oriented for service design.	Kim and Park (2012)
Checklist to assess the sustainability of PSS.	Shih et al. (2009)
IPs were reinterpreted and oriented for innovation in PSS.	Chen and Li (2010)

26 reinterpreted IPs were oriented for innovation in PSS.	Yang and Xing (2014)
A PSS 109 case database table for identifying the relationship between eco-efficiency and service effectiveness.	Chen and Huang (2011)
Groups the 40 IPs in five categories (self-service, direct service, pre-service, bundled service and physical service).	Gazem and Rahman (2014a; 2014b)
A detailed case database of 75 low-carbon PSS.	Chen and Liu (2012)
The eco-leasing low-carbon effect comparison value (ELCV) and low-carbon effect value (ELV) index.	Chen and Jiao (2014)
IPs with examples in PSS.	Kim and Yoon (2012)
IPs were revised to solve service contradictions	Chai, Zhang and Tan (2005)
Interpretation of 40 IPs to the B2C service context	Gazem and Rahman (2012)

The major advances and contributions identified can be classified in three main categories: (i) assessments: compost by several types of low-carbon index to assess the SSPSS design process; (ii) case database: included data base of PSS cases to support the systematic benchmarking, and (iii) different reinterpretations of IPs to obtain systematic innovation in service design (e.g. B2B business) and in PSS design. On the whole, the major systematic contributions highlighted suggest improvements and modified TRIZ tools adjusted to support the servitization process and different strategies of sustainability assessment for PSS design. The extensive application and validation of these strategies are indicated to obtain a consolidated set of systematic tools accepted by academics, professionals and enterprises evolvolving in PSS field. The 40 IPs to service context seems to be advancing in this direction.

Moreover, based on the results and aiming to explore the benefits of structured TRIZ tools, we identify the opportunity to test other robust environmental tools to leverage the sustainability impact in PSS design. In this sense, the opportunity emerges to integrate others tools with environmental proposals that are available and tested with TRIZ in different contexts of PSS design, such as QFDE (QFD for Environment) in Bereketli and Genevois (2014), Life Cycle Assessment (Yang and Chen, 2011), Biomimetic (Chen and Yang, 2011; Bogatyreva et al., 2003) and eco-design (Russo, Regazzoni and Montecchi, 2011; Russo, Rizzi and Montelisciani, 2014).

Regarding the systematic tools, a relevant insight and contribution of results in a lifecycle perspective of PSS is that, in general, because it is a topic still in development (mainly in small and medium enterprises), the PSSs are at the beginning of their S-Curves development. Thus, the S-Curve tool integrated with Trends of Evolution and IFR tools can be a good strategy for systematically achieving a radical value proposition for customers and new sustainable development stages in PSS design. In short, considering the main advances identified, a relation of the main contributions of methods, tools or frameworks developed based on systematic innovation of TRIZ could be summarized (Table 4). These related contributions could be a bottom line for new sustainability-oriented research studies based on systematic eco-innovations in PSS design.

We also found that, due to 65% of the papers having been published since 2010, this research topic is in a developing stage, having progressed in past years and gained attention from academics. Considering the varied contexts of research studies, the findings show a lack of a dominant research direction in this relevant topic. Thus, to achieve more maturity in this field, there is the pressing need for further research studies involving a larger number of case studies (Chen and Huang, 2011). The outcomes also showed other research opportunities on contingences and contextual aspects. Due to the results having showed the lack of a dominant research direction, there is a need for further deep research studies that propose rigorous research to understand certain contingences (e.g., segment, size, and type of PSS).

Moreover, based on results, another aspect to consider is that the rapid growth of research fields from an individual perspective (e.g., PSS business models and TRIZ) can contribute to problems associated with accumulating and systematizing findings. From this conclusion, there is a growing trend in research on the integration of sustainable PSS and TRIZ because more systematic and structured managerial methods and tools are necessary (Rondini et al., 2016; Qu et al., 2016; Omann, 2003) along with the servitization.

Hence, research studies oriented to develop constructs or typologies to define concepts about the integration between TRIZ and PSS are a necessary step, aiming to avoid problems associated with accumulating and systematizing in new research studies (Reim, Parida and Ortqvist, 2015). In this same direction, research efforts should be made to, in particular, assess the performance criteria of new systematic methods developed to support the PSS design. It is important due its great potential to minimize the barriers associated with the lack of knowledge in PSS business models within companies.

Finally, we conclude that because the research topic focusing on the systematic PSS transition is far from being a mature discipline in the PSS field, there are no currently methodologies, methods or even reference models developed that have become a standard artifact accepted between the academic community and professionals evolving in the servitization area. Similarly, there is thus far also no reference model or method for the design of PSSs. Our findings, in turn, have shown that the systematic innovation proposals of TRIZ could contribute to fill these research gaps, enabling more systematic and sustainable PSS business models supported by structured methods.

7.6 Conclusions and Research Directions

Our research investigated how the methods and tools of TRIZ are applied in the transition toward sustainable PSS and might contribute to a more efficient and systematic servitization process. The analysis was centered in the following main perspectives: the most cited authors and papers, the network of relationships between them, which tools, techniques and methods of TRIZ are frequently applied in PSS, identification of the main advances and contributions to the field, and the research gaps. The main contribution of our research was the presentation of a structured aggregation of knowledge regarding existent tools and methods of TRIZ applied to systematic servitization to assist companies in systematically designing and implementing SPSS business models.

The findings revealed the most frequent TRIZ tools applied in PSS (e.g., 40 IPs and the Contradiction Matrix). Hence, verifying the efficiency of other TRIZ tools that have been less explored (e.g., AFD, SLP, and 9 Windows) in previous PSS literature is an important research opportunity. During our research, the possibility for the integration of other engineering methodologies to leverage the sustainable potential of PSS design for applying TRIZ was also verified. In this direction, we suggest more studies integrating QFDE (Bereketli and Genevoi, 2013), LCA (Yang and Chen, 2011), Biomimetic (Bogatyreva et al., 2003) and Eco-design (Navas, 2013; Russo, Rizzi and Monteslisciani, 2014). Lastly, regarding the tools, a relevant insight and contribution of results in a life cycle perspective, is that this research field is still in an early stage from the perspective of lifecycle analysis of sustainability in PSS design. As a result, many definitional elements are still under development, and several research opportunities exist in this direction.

Result-oriented PSS are thus far the most unconventional PSS and have a large potential for sustainability benefits (Tukker, 2004; Barquet et al., 2016). Nonetheless, only 32% of the studies that adopted TRIZ tools are in the result-oriented category. Hence, new research studies and methods in this category exploring this potential for sustainability are recommended. The findings of this systematic review identified a set of primary advances and contributions with TRIZ into SPSS, as summarized in Table 4. Aiming to consolidate these contributions, we suggest new studies based on case studies that apply and discuss new developments of these systematic tools and insights.

Moreover, the current research framework pays little attention to producer and cost perspectives, which are also crucial in the process of PSS evaluation and operation. Even more criteria should be identified to evaluate the efficiency of PSSs (Qu et al., 2016). A bottom line in this direction may be the studies by Chen and Jiao (2014), Chen and Liu (2012) and Chen and Huang (2011).

More quantitative research studies combining TRIZ in PSS need to be conducted in the future. Compared with qualitative studies, quantitative ones may be more effective to demonstrate the influence of PSS on the micro and macro economy, society and the environment. Nevertheless, researchers should pay attention to the capacity of absorption of these quantitative methodologies by companies, which generally face “lack of knowledge within firms” (Vezzoli et al., 2015, p. 8). No study involving the use of TRIZ and PSS in a B2G context was identified in the literature, leaving this as a future research opportunity for this type of company. Researchers from Asia and Europe were responsible for approximately 94% of research on this topic. Therefore, there is a large research opportunity for academics and practitioners of PSS and TRIZ in other regions of the world (e.g., Africa and the Americas). Comprehending the causes of this aspect may also be an opportunity for new research efforts. Future researches also could try to understand certain contingences such as the segment of company or size (large versus SMEs), for example.

Were identified limitations in this study. First, even if our search process had covered the main collections and scientific databases (e.g., Scopus, ProQuest, B-on and TRIZ Conferences and Journals), others sources, such as privative databases of universities or even a deep look into gray literature, were not considered. Second, we considered only English journal articles, excluding books and papers published in other languages. We would like to address these limitations as suggestions and opportunities for future research. Despite all of these limitations, our study has contributed to comprehending the state-of-the-art of PSS design, evaluation, and operation methodologies.

Finally, based in our results and on gaps in the literature (Qu et al., 2016; Vezzoli et al., 2015; Ceschin, 2013) that indicate the need for systematic and structured methods/tools to support servitization, we conclude that the integration of TRIZ into the PSS domain is a promising research field. This occurs because TRIZ enable more effectiveness in Systematic and Sustainable PSS (SSPSS) design. Our findings have shown that TRIZ may effectively contribute to fill gaps regarding why SPSS has not been widely implemented, providing a relevant scope of research for the scientific and industrial community operating in this emergent field.

Acknowledgements

This research was supported by Portuguese Foundation for Science and Technology (FCT) and by Brazilian Council for Scientific and Technological Development (CAPES/CNPq) under grant number 230916.

REFERENCES

Abdalla, A., Bitzer, B., Morton, D. 2004. Benchmarking TRIZ in the field of product service systems PSS, In: Proceedings of the 4th ETRIA TRIZ Future Conference, Florence, Italy.

Abdalla, A., Bitzer, B., Morton, D. 2005. Innovation management methods and tools for sustainable product service systems (With a Case Study). TRIZ Journal, April.

Altshuller, G. 1999. The innovation algorithm: TRIZ, systematic innovation, and technical creativity. Worchester, Massachusetts: Technical Innovation Center. 312 p.

Altshuller, G. 2004. And Suddenly the Inventor Appeared. edited by S. Shulyak, Lev; Rodman. Worcester, MA: Technical Innovation Center, Inc..

Baines, T., Lightfoot, H., Benedettini, O., Kay, J. 2009. The servitization of manufacturing: a review of the literature and reflection on future challenges, Journal of Technology Management, 20 (5), 547-567.

Barquet, A. P., Seidel, J., Seliger, G., Kohl, H. 2016. Sustainability factors for PSS business models. Procedia CIRP 47, 436 – 441.

Becker, J., Beverungen, D., Matzner, M., Müller, O., Pöppelbu, J. 2011. Design Science in Service Research: A Framework-Based Review of IT Artifacts in Germany. In: Proceedings of 6th International Conference, DESRIST. USA.

Bereketli, I, Genevois, M. E. 2014. An integrated QFDE approach for identifying improvement strategies in sustainable product development. Journal of Cleaner Production 54 (1), 188–198.

Bogatyreva, O., Phal, A.K., Bowter, A., Vincent, J. 2003. Data Gathering for Putting Biology in TRIZ. In: Proceedings of 5th Annual Conference of the Altshuller Institute for TRIZ Studies, Pennsylvania, USA.

Cavalieri, S., Pezzotta, G. 2012. Product–Service Systems Engineering: State of the art and research challenges, Computers in Industry, 63 (4), 278–288.

Ceschin, F. 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production 45, 74-88.

Chai, K. H., Zhang, J., Tan, K. C. 2005. A TRIZ-Based method for new service design. Journal of Service Research 8, 48-66.

Chechurin, L. 2016. TRIZ in science. Reviewing indexed publications. Procedia CIRP 39: 156 – 165.

Chechurin, L., Borgianni, Y. 2016. Understanding TRIZ through the review of top cited publications. Computers in Industry 82, 119–134.

Chen, C. -K., Shie, A. -J., Wang, K. -M., & Yu, C.-H. 2015. An Ageing-in-Place Service Innovation Model by Using TRIZ Methodology. Human Factors and Ergonomics in Manufacturing & Service Industries 25 (2), 166–182.

Chen, L. J., Jiao, W. S. 2014. TRIZ Innovative Design Method for Eco-leasing Type Product Service Systems. Procedia CIRP 15, 391-394.

Chen, J. L., Liu, Y. 2012. Innovative Design and Assessment of Low-carbon Emission Concept Product Service Systems. In: Proceedings of the 4th CIRP International Conference on Industrial Product Service Systems (IPS2 2012), Tokyo, Japan, 369-374.

Chen, J. L., Huang, S. C. 2011. Eco-Innovative Design of Product Service Systems by using the Substance-Field Analysis Method. In: Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems (IPS2 2011), Braunschweig, Germany, 63-68.

Chen, J. L., Jiao, Wei-Su. 2014. TRIZ Innovative Design Method for Eco-leasing Type Product Service Systems. In: Proceeding of 21st CIRP Conference on Life Cycle Engineering, Procedia CIRP 15, 391 – 394.

Chen, J.L., Li, H. C. 2010. Innovative Design Method of Product Service System by Using Case Study and TRIZ Method. In: Proceedings of the 2nd CIRP international Conference on Industrial Product Service Systems (IPS2 2010), Linköping, Sweden, 299-305.

Chen, J.L., Yang, Y. C. 2011. Eco-Innovation by Integrating Biomimetic with TRIZ Ideality and Evolution Rules. In: Proceedings of 18th CIRP International Conference on Life Cycle Engineering, Braunschweig, Germany, 101-106.

Dahmani, S., Boucher, X., Gourc, D., Marmier, F., Peillona, S. 2014. Towards a reliability diagnosis for servitization decision-making process. Procedia CIRP 16, 259 – 264.

Doualle, B., Medini, K., Boucher, X., Brissaud, D., Laforest, V. 2016. Design of sustainable product-service systems (PSS): towards an incremental stepwise assessment method. Procedia CIRP 48, 152 – 157.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research:A Method for Science and Technology Advancement. Springer. pp.161.

Fan, H., Sheng, Z. 2014. Research on Conceptual Design of Product Service System Oriented on CNC Machine Tools. Advanced Materials Research 889-890, 1471-1480.

Fresner, J., Jantschgi, J., Birkel, S., Barnthaler, J., Krenn, C. 2010. The theory of inventive problem solving (TRIZ) as option generation tool within cleaner production projects. Journal of Cleaner Production 18: 128–136.

Fulea, M., Brad, S. 2011. Ontology-Based Approach for Supporting Creativity in a PSS Design Methodology. In: Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems (IPS2 2011), Braunschweig, Germany, 75-80.

Gadd, K. 2011. TRIZ for Engineers. John Wiley & Sons, West Sussex, UK.

Gazem, N.A. J., Rahman, A.B.A. 2014a. Redesign Services using Inventive Principles: A Case Study, Journal of Information Service Systems Innovation 2, December, 126-132.

Gazem, N.A. J., Rahman, A.B.A. 2012. Interpretation of TRIZ Principles in a Service Related Context Asian Social Science 10 (13), 108:130.

Gazem, N.A. J., Rahman, A.B.A. 2014b. Improving TRIZ 40 Inventive Principles Grouping in Redesign Service Approaches. Asian Social Science 10 (17), 127-138.

Gough D, Oliver S, Thomas, J. 2012. An Introduction to Systematic Reviews. London: Sage. Publications, 304 p.

Gregor, S., Hevner, A. R. 2013. Positioning and presenting design science research for maximum impact. MIS Quarterly 37 (2), 337-355.

Harzing, A.W., 2007. Publish or Perish. Available from: http://www.harzing.com/pop.htm.

Hevner, A. R., March, S. T., Park, J., Ram, S. 2004. Design science in information systems MIS Quarterly 28 (1), 75-105.

Ilevbare, I. M., Probert, D., Phaal, R. 2013. A review of TRIZ, and its benefits and challenges in practice. Technovation 33, 30–37.

Ikovenko S., Bradley, J. 2004. TRIZ as lean thinking tool. In: Proceeding of 4th TRIZ Future Conference, Florence, Italy.

Ilevbare, M. I., Probert, D., Phaal, R. 2013. A review of TRIZ, and its benefits and challenges in practice. Technovation 33, 30–37.

Jie, J., Yan, L., Xiong, Y., Wen-Qiang, L. 2013. Product service systems innovative design based on TRIZ final ideal solutions and function stimulation. Computer Integrated Manufacturing Systems 19 (2), 225-234.

Kim, S., Park, Y. 2012. A TRIZ-based Approach to Generation of Service-supporting Product Concepts. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering 6 (2), 487-490.

Kim, S., Yoon, B. 2012. Developing a process of concept generation for new product-service systems: a QFD and TRIZ-based approach. Service Business 6, 323–348.

Kjaer, L.M., Pagoropoulos, A., Schmidt, J. H., McAloone, T.C.2016. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. Journal of Cleaner Production 120, 95-104.

Kubota, F. I., Rosa, L. C. 2013. Identification and conception of cleaner production opportunities with the Theory of Inventive Problem Solving. Journal of Cleaner Production 47, 199–210.

Lelah, A., Boucher, X., Moreau, V., Zwolinski, P. 2014. Scenarios as a tool for transition towards sustainable PSS. In: Proceedings of 6th CIRP International conference on Industrial Product-Service Systems, 122-127.

Li, N., Jiang, Z. 2013. Modeling and optimization of a product-service system with additional service capacity and impatient customers. Computers & Operations Research 40 (8), 1923–1937.

Lin, C.-S., & Su, C.-T. (2007). An Innovative Way to Create New Services: Applying the TRIZ Methodology. Journal of the Chinese Institute of Industrial Engineers, 24(2), 142-152.

Low, M. K., Trond, L., Kathryn, W., Odd, M. 2001. Manufacturing a green service: engaging the TRIZ model of innovation. IEEE Trans Electron Packag Manuf. 24 (1), 10–17.

Mann, D., Jones, E. 2002. Sustainable Services & Systems (3s) through systematic innovation methods. The Journal of Sustainable Product Design. 2 (3), 131-139.

Mann, D. 2002. Manufacturing technology evolution trends. Integrated Manufacturing Systems 13 (2), 86-90.

March, S. T. and Smith, G. F. 1995. Design and natural science research on information technology. Decision Support Systems 15 (4), 251-266.

Menor, L., Tatikonda, M. V., Sampson, S.E. 2002. New service development: area for exploitation and exploration. Journal of Operations Management 20, 135–57.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. 2009. The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097.

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

Nakagawa, T. 2011. USIT: A New Paradigm for Creative Problem Solving - It´s Concept and Usage. In: Proceeding of 7th TRIZ Symposium, Japan TRIZ Society, NPO. Yokohama, Japan.

Navas, H.V.G. 2014. In: Garrido SA, Brandenburg M, Carvalho H, Cruz-Machado V. Eco-Innovation and the Development of Business Models. Ed. Springer International Publishing., 314 p.

Navas, H. V. G. 2013. TRIZ: design problem solving with systematic innovation. In: Denis AC (ed) Advances in industrial design engineering. Rijeka, Croatia, InTech, 75–97.

Omann, I. 2003. Product-service systems and their impacts on sustainable development – a multi-criteria evaluation for Austrian companies. Frontiers, 1-34.

Paiola, M., Gebauer, H., Edvardsson, B. 2012.Service Business Development in Small-to Medium-Sized Equipment Manufacturers. Journal of Business-to-Business Marketing 19 (1), 33-66.

Pezzotta, G., Regazzoni, D., Cavalieri, S., Rizzi, C. 2009. A TRIZ-based approach for Product-Service Engineering. In: Proceedings of Quaderni della XV Summer School Impianti Industriali Meccanici - Sustainable Development: The Role of Industrial Engineering, Monopoli, Italy.

Pezzotta, G., Regazzoni, D., Cavalieri, S., Rizzi, C. 2011. Enhancement in Industrial PSS Design based on TRIZ: a Case Study. In: 3th CIRP International Conference on Industrial Product Service Systems, Braunschweig, Germany, 225-230.

Pigosso, D. C.A., McAloone, T. C. 2016. Maturity-based approach for the development of environmentally sustainable product/service-systems. CIRP Journal of Manufacturing Science and Technology. In press.

Qu, M., Yu, S., Chen, D., Chu, J., Tian, B. 2016. State-of-the-art of design, evaluation, and operation methodologies in product service systems. Computers in Industry 77, 1-14.

Regazzoni, D., Pezzotta, G., Persico, S., Cavalieri, S., Rizzi, C. 2012a. Integration of TRIZ problem solving tools in a product-service engineering process. In: Proceedings of 4th CIRP International Conference on Industrial Product-Service Systems, Tokio, Japan, 399-404.

Reim, W., Parida, V., Ortqvist, D. 2015. Product e Service Systems (PSS) business models and tactics e a systematic literature review. Journal of Cleaner Production 97, 61-75.

Rondini, A., Pezzotta, G., Pirola, F., Rossi, M., Pina, P. 2016. How to design and evaluate early PSS concepts: the Product Service Concept Tree. Procedia CIRP 50, 366 – 371.

Rovida, E., Bertoni, M., Carulli, M. 2009. About the use of TRIZ for product-service development. In: Proceedings of 17th International Conference on Engineering Design - ICED, Stanford, USA, 133-145.

Russo, D., Regazzoni, D., Montecchi, T. 2011. Eco-design with TRIZ laws of evolution. In: ETRIA World TRIZ Future Conference 9, 311-322.

Russo, D., Rizzi, C., Montelisciani, G. 2014. Inventive guidelines for a TRIZ-based eco-design matrix. Journal of Cleaner Production 76, 95-105.

Savransky, S. D. 2001. Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving. CRC Press, Boca Raton New York, 1st Ed. 394 p.

Shih, Li-Hsing., Chen, J.L., Tu, Jui-Che., Kuo, Tsai-Chi., Hu, A. H., Lin, Sheng-Lung. 2009. An integrated approach for product service system development: I. Design phase. J. Environ. Eng. Manage. 19 (6), 327-342.

Shimomura, Y., Hara, T. 2010. Method for supporting conflict resolution for efficient PSS development. CIRP Annals - Manufacturing Technology 59, 191–194.

Smith, M., Ceni, A., Milic-Frayling, N., Shneiderman, B., Mendes Rodrigues, E., Leskovec, J., Dunne, C., 2010. NodeXL: a free and open network overview, discovery and exploration add-in for Excel 2007/2010/2013/2016. http://nodexl.codeplex.com/ from the Social Media Research Foundation. http://www.smrfoundation.org.

Song, W., Sakao, T. 2016. Service conflict identification and resolution for design of product–service offerings. Computers & Industrial Engineering 98, 91–101.

Storbacka, K., Windahl, C., Nenonen, S., & Salonen, A. (2013). Solution business models: Transformation along four continua. Industrial Marketing Management, 42(5), 705–716.

Tranfield, D., Denyer, D. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14 (3), 207-220.

Tukker, A. 2015. Product services for a resource-efficient and circular economy - A review. Journal of Cleaner Production 97, 76-91.

Tukker, A. 2004. Eight types of Product-Service System: Eight ways to sustainability? Experiences from SusProNet. Bus. Strategy Environ. 13, 246–260.

Venable, J., Pries-Heje, J. Baskerville, R. 2012. A comprehensive framework for evaluation in design science research. In: Proceedings of DESRIST, Las Vegas, NV, 423-438.

Vezzoli, C., Ceschin, F., Diehl, J. C., Kohtala, C. 2015. New design challenges to widely implement 'Sustainable Product–Service Systems. Journal of Cleaner Production 97 (15), 1–12.

Vidal, R., Salmeron, J. L., Mena, A., Chulvi, V. 2015. Fuzzy Cognitive Map-based selection of TRIZ (Theory of Inventive Problem Solving) trends for eco-innovation of ceramic industry products. Journal of Cleaner Production 107 (16), 202–214.

Vieira, L. C., Amaral, F. G. 2016. Barriers and strategies applying Cleaner Production: a systematic review. Journal of Cleaner Production 113, 5-16.

Yang L, Xing K. A. 2014. Concept Innovation Model for Product Service Systems Development and Application. IEEE. Beijing, China.

Yang, C. J., Chen L. J. 2011. Reasoning New Eco-Products by Integrating TRIZ with CBR and Simple LCA Methods. In: Proceedings of 18th CIRP International Conference on Life Cycle Engineering, Braunschweig, Germany, 107-112.

Yang, J. C., Chen, L. J. 2011. Accelerating preliminary eco-innovation design for products that integrates case-based reasoning and TRIZ method. Journal of Cleaner Production 19, 998-1006.

Yang, L., Xing, K. 2013. Innovative Conceptual Design Approach for Product Service System based on TRIZ. IEEE. 247 – 252.

Yoon, B., Kim, S., Rhee, J. 2011. An evaluation method for designing a new product and service system. Expert Syst. Appl. 39 (3), 3100-3108.

Zhang, J., Tan, K., and Chai, K. 2003. Systematic Innovation in Service Design Through TRIZ. TRIZ Journal. September.

Zhang, J., Chai, K.-H., & Tan, K.-C. (2005). Applying TRIZ to service conceptual design: an exploratory study. Creativity and Innovation Management, 14(1), 34-42. dx.doi.org/10.1111/j.1467-8691.2005.00323.

Wu, Y. 2012. An Integrated Approach for Concept Generation in New Service Development. Advances in information Sciences and Service Sciences 4 (15), 134-141.

CAPÍTULO VI

The main implications and contributions of this Chapter to this thesis were the following:

- The previous accumulate results obtained in the chapters 2, 3, 4 and 5 were used as bottom line to conduce this stage of research.
- An eco-innovation-oriented reference method to support SPSS proposals for manufacturing SMEs was proposed and successively validates specialists in PSS field.
- Successive stages of enhance of the method, including or modifying tasks, phases, interactions between the phases and tools was performed.

8 Artigo 7: A Eco-innovation-oriented Reference Method to Support SPSS Proposals for Manufacturing SMEs

Abstract

The analysis of gap from literatures and the previous outcomes in the chapters 2, 3, 4 and 5 reinforced the need of establish an effective contribution to SPSS literature developing a reference method to support the SMEs to design SPSS proposals. Several factors, tools, elements and lessons learned from literature emerged from chapters 2, 3, 4 and 5. Therefore, the purpose of this study is integrate these previous insights and findings combining with others methodologies and research techniques to purpose an eco-innovation-oriented reference method to support the SPSS design proposals for manufacturing SMEs. In order to achieve this goal, based on the guidelines from literature on research method, this study adopted a sequence of three Focus Groups to purpose and validates the proposed method. Results from literature, indicate that Focus Group is an indicated method of qualitative research to complement previous research methods in a research. This is the case of findings obtained in chapter 2, 3, 4 and 5. Hence, a sequence of steps was applied to validate and enhance the method. As final results of this study, and summed up with the integration of results obtained in previous chapter, a reference method was proposed and successively validated.

8.1 Introduction

Results obtained in the second chapter of this research indicated that the debate on eco-innovation, although recent, is becoming increasingly more relevant in the practical context of business and academic world. The discussion on eco-innovation in the context of manufacturing SMEs is in a less developed stage and deserves attention. Moreover, in this chapter a list of twenty-three determinants of the eco-innovation in manufacturing SMEs were classified in seven categories. Particularly, the prevalence of a product and process eco-innovation oriented methods was one of critical determinants resulting. Similarly, in the discussions made in the chapter five, the outcomes indicated that researches focusing on the systematic SPSS transition are far from being a mature research topic. There are no currently methodologies, methods or even reference models or methods accepted between the academics and professionals evolving in the servitization area. Thus, the systematic innovation proposals of TRIZ may contribute to fill this research gap, enabling more systematic and sustainable PSS business models supported by structured methods.

Furthermore, in the third chapter of this study a very recent increase interest by Sustainable Product-Service System (SPSS) topic in recent years was evidenced. This occurs, among other reasons because, on one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. However, on the other hand, SPSS concept is based on eco-efficiency and embedded in a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy. Therefore, SPSS may be considered a more robust and prosper discipline. This chapter also concluded on the need of the proposition of systematic and easy-use methods and tools integrating the life cycle of a SPSS offer (Beginning-Of-Life, Middle-Of-Life and End-Of-Life) in order to minimize the effects of lack of competence of SMEs supporting the sustainable transformation.

Due their global economic relevance a special look to SMEs should be given. For example, at least 80% of all global enterprises are considered SMEs (Moore and Manring, 2009) and according to European Commission (2011) SMEs represent with over 99% of European enterprises and two-thirds of European employments. Therefore, they can be considered a key actor to the global economy.

In this same line, in the discussions made in the fourth chapter in the perspective of a new method, was found that the integration between service engineering structured tools with Business Model Canvas or Design Thinking approaches results in more effective methods supporting transition and helping to internalize some required competences in SMEs (Xing and Ness, 2016; Orloff and Heinz, 2015; Pardo, 2012). In short, is possible state that the proposition of new eco-innovation-oriented methods is a relevant and necessary step to advance towards effective SPSS business models, allying sustainable innovations and reduction in environmental impacts.

Thus, the elements, determinants, tools and guidelines obtained in previous chapter together with successive stages of validation by adopting focus groups were mobilized to develop a reference method. The essential purpose of focus group research is to identify a range of different views around the research topic, and to gain an understanding of the issues from the perspective of the participants themselves. The group context is intended to collect more wide-ranging information in a single session than would result from one-to-one interviews (Hennink, 2007).

Focus group research is a way to conduct data gathering having qualitative nature and aims to understand the considerations made by a group of people after an experience, idea, or event. The focus group also can be perceived as an in-depth interview that occurs in groups with structured sessions that contemplate the proposal, the size, the components, and the procedure for conducting the group (Dresch et al, 2015). The increased use of focus group discussions is partly due to a broader acceptability of qualitative methods in social sciences, but also due to a greater emphasis on the inclusion of qualitative methods in mixed-method research designs, to respond to research issues not accessible by quantitative approaches (Hennink, 2007).

8.2 Research method

The following sections were developed following the definitions and stages proposed by Hennink (2007) to a successful realization of Focus Group in academics research. This thesis follows the statements and steps proposed by Hennink (2007) to conduce Focus Groups.

8.2.1 Definition and Types of Focus Group

A Focus Group discussion is a unique method of qualitative research that involves discussing a specific set of issues with a pre-determined group of people. The essential purpose of focus group research is to identify a range of different views around the research topic, and to gain an understanding of the issues from the perspective of the participants themselves.

Nowadays, there are four accepted and distinct styles of Focus Group research: the market research approach, the academic application, use by non-profit organisations and participatory approaches. In this sense, this research adopts the academic focus group. This approach to focus group discussions is much more focussed on the careful application of a research method, the generation of quality data and detailed, rigorous analysis of the information; therefore this approach takes considerable time (Hennink, 2007).

8.2.2 Justification and Advantages of Focus Group to this research

Focus Group is an effective tool for exploratory, explanatory or evaluative research, and can provide useful information for policy and practice. This research can be classified as both exploratory and evaluative research (Hennink, 2007). Exploratory research is conducted when little is known about a research issue. This was evidenced by the literature gaps demonstrating the absence of eco-innovation-oriented methods supporting SPSS design proposals to manufacturing SMEs (see chapter 1, 2, 3 and 4). It also may be used to identify new issues, define research hypotheses, or to provide background information about a topic or study population.

Already the evaluative research is conducted when assessing the effectiveness of a service, programme or initiative. It may be used in program planning or re-development. In this case, this research also could be considered evaluative because the goal of three Focus Group performed was evaluate and validate the proposed versions of method during it development and cycles of improvements (M1, M2). Therefore, the general structure and interfaces between the three Focus Groups are the following:

Table 1 – Structure of three Focus Groups

Focus Group	Duration	Input	Objectives	Outputs
Focus Group 1	2h:03min	Gaps from literature identified in the papers 1, 2, 4, 5 and 6. The version M1 of proposed method developed from results of systematic literature review study by Cavalieri	Define the appropriate stages, tasks and tools for the life cycle of the PSS design (BOL, MOL, EOL) adapted to the manufacturing SMEs.	As result, were suggested appropriate stages, tasks and tools for the life cycle of the PSS design suited to the manufacturing SMEs. Bottom line to develop the version M2 of proposed method

		and Pezzotta (2012).		
Focus Group 2	2h:39min	Gaps from literature identified in the papers 1, 2, 4, 5 and 6. Was adopted the study by Yang et al. (2017) as bottom line and extension.	To extend the main categories of sources of value uncaptured and the detailed aspects across the PSS life cycle to SMEs. To define strategies to increase the added value in each phase of PSS life cycle suited to SMEs.	New categories of sources of value uncaptured and detailed aspects to SMEs were complemented. The study by Yang et al. (2017) was complemented. Bottom line to develop the eco-innovation elements to the version M2 of proposed method.
Focus Group 3	2h:26min	Version M2 of proposed method	To validate and insert in M2 new elements of value addition to customers in a sustainable perspective (environmental, social and economic) To validate the general architecture among the actors of the method and proposed new connections/interactions To validate and improve method M2 current proposing new phases, tasks, tools and interactions.	New elements of value addition to customers were complemented in M3. Was validated the general architecture between the actors and interactions emerged to M3. New phases, tasks, tools was incorporated in M3. Based in these results, the version M3 of method was developed.

Particularly, the focus group was chosen to this research for the following main reasons and advantages. In the first Focus Group (oriented to the M1), aiming identify new insights from specialists' vision on PSS life cycle (phases, tasks and suited tools) to the SMEs context. As well as, to provide background on the mains interactions between actors versus phases able to improve the value addition to customers.

In the second Focus Group, was used aiming enhance the version M1, to extend the main categories of sources and aspects of value uncaptured (Yang et al., 2017) across the PSS life cycle suited to SMEs environment. As well as, new insights and propositions to increase the added value along the PSS life cycle to SMEs. Finally, in the third Focus Group (oriented to the M2), it was suited to attend the goal of validation, extension and improve of the method (M2) developed from previous stages, resulting in M3.

Based in the research objectives of this research the following justifications also clarify the choice of this approach.

Focus group discussions are suitable for exploratory research to identify new issues, to consolidate research hypotheses, or to provide background information about a topic or a study population about which little is known. Considering that this research is exploratory, Focus Group is suited to new and immature research topics, as is the case of this research.

Besides, the group context of a focus group makes it an ideal method when seeking a range of views on a topic, when debate and discussion on an issue is desired and for uncovering new insights or unanticipated issues. Due to the distinct background of specialists in PSS field evolving in the three Focus Group, a range of views may contribute with useful insights to develop the method supporting SPSS design proposals in manufacturing SMEs.

Focus group discussions are most suitable when seeking community-level information (as opposed to personal information). In this sense, seeking for consensus and consolidate insights and information from participants. Such as for example, defining the most suited activities and tools that the method of this work should have.

Focus groups are suitable for provoking a discussion and are therefore useful when seeking justifications and explanations of issues. The discussion between the experts is a beneficial source of information based in the background of experts in PSS.

Focus group discussions may be used in evaluation research as a diagnostic tool to examine their effectiveness. This justification particularly is applicable to first Focus Group performed to validate the method M1, and to the third Focus group, realized to validate the version M2, resulting in the version M3.

The advantages of focus group discussions also are in the socially oriented nature of this research procedure, the variety of applications of the method and the group environment of data collection. Considering the social aspects evolving the PSS design, it is possible affirms that Focus groups is a suited research method to collect new insights to the development process of a new method supporting PSS proposals.

8.2.3 Collecting Data and Coding

The three focus groups adopted the same process to the organization, protocol, collecting data and coding. For the accomplishment of focused groups, initially an initial contact with the experts was made by e-mail, confirming the acceptance and availability for the scheduled date. In addition, in the next step, each specialist received with antecedence a document with the preparation guidelines for the specific Focus Group (Appendix A, B and C).

The information collected during the three Focus Groups was recorded in both audio and video resources. The discussion was recorded with audio/video resources camera. Moreover, an auxiliary device recording only audio was used as redundancy. Finally, the participants also were encouraged to write the answers regarding to the questions (Introductory questions, Key questions and Ending questions) in a respective form available (Appendix D, E and F).

The objective of collect multiples source of primary data was permitted solve possible doubt, avoiding failures and ensuring the reliability during the process of coding and content analysys. This strategy also is useful to minimize the effect when not all participants verbalize an answer during the debate to each question of Focus Group. Thus, the three sources of primary data were analysed to ensure the reliability of analyses (audio/video and writing).

Before begin each session of Focus Group, each participant also fills a specific form with information about personal profile, industrial/academic background and experience in PSS and also the Term of Participation and Accept (Appendix H). This Term of Participation and Accept informed the consent of participants to be part of discussion providing sufficient and accurate information to the participants in a comprehensible format that participants can make an informed and voluntary decision on whether or not to participate. It was assigned by each specialist.

According to Hennink (2007) the information collected in the group discussions is treated as data and recorded in various forms, by notes, tape recording and transcription of the discussion. The written transcripts form the basis of data analysis, which follows an accepted scientific protocol, and may involve the use of specially designed software programs to code, categorise and interpret the findings. The research results are published in academic, technical or policy reports and the data are used to justify the findings.

The audio and video data were transcribed and coded with the help of the software NVIVO 11. During the first coding cycle the specialist's responses were characterized using the code corresponding to the questions asked. In the second coding cycle, each grouping of coded stretches was re-evaluated and recoded seeking new insights and valid knowledge for the purpose of each focused group. As a result of this process and in the horizontal and vertical analysis between the participants' answers, the sections of the main answers of the specialists were grouped. As a result, we obtained different sets of categories and subcategories, new insights and contributions to the elaboration in the method.

According to Schreier (2014), the qualitative content analysis is a method for systematically describing the meaning of qualitative data. This is done by assigning successive parts of the material to the categories of a coding frame. Three features characterize the method: qualitative content analysis reduces data, it is systematic, and it is flexible. These aspects are detailed according to Schreier' propositions as follow:

Qualitative content analysis reduces data. Unlike other qualitative methods for data analysis which open up (and sometimes add to) data, qualitative content analysis helps with reducing the amount of material. It requires the researcher to focus on selected aspects of meaning, namely those aspects that relate to the overall research question. The number of categories and subcategories is limited by the number of categories a researcher can handle. Also, when defining the categories, one will usually go beyond the specifics of any particular passage. Instead, the meaning of the passage will be taken to a higher level of abstraction, resulting in categories that apply to a number of concrete, slightly different passages.

Systematic. A second key feature of qualitative content analysis is that it is highly systematic. To start with, the method requires the examination of every single part of the material that is in any way relevant to the research question. The method is also systematic in that it requires a certain sequence of steps, regardless of the exact research question and material. As is often the case in qualitative research, this may be an iterative process, going through some of these steps repeatedly, modifying the coding frame in the process. But the steps and their sequence remain the same. The method is also systematic in that it requires coding (i.e. assigning segments of the material to the categories of the coding frame) to be carried out twice (double coding), at least for parts of the material. This is a test of the quality of the category definitions: they should be so clear and unambiguous that the second coding yields results that are very similar to those of the first coding.

Flexible. A third key feature of qualitative content analysis – especially by comparison with the quantitative version is its flexibility. Qualitative content analysis typically combines varying portions of concept-driven and data-driven categories within any one coding frame. At the same time, a part of the categories should always be data-driven. This is to make sure that the categories in fact match the data – or, to put it differently, that the coding frame provides a valid description of the material. Qualitative content analysis is therefore flexible in that the coding frame should always be matched to the material.

Induction, deduction and also abduction are forms of logical reasoning that are used in every type of research, both qualitative and quantitative alike. Together with observation, they create the basis of all research. These forms of thinking are not concepts, nor are they methods or tools of data analysis, but means of connecting and generating ideas. Because they represent the intellectual building blocks of research, they are method neutral (Reichertz, 2014). Along the stages of content analysis, this study applied particularly, deduction and also abduction logical to represent the outcomes.

A summary of elements, based in Reichertz' statements, helps to comprehend the application of abductive and deductive thinking. Regarding to Abduction: (i) It begins when the human actor is taken by surprise, and it ends when the surprise is replaced by understanding and the ability to make predictions; (ii) The starting point for any abduction is empirical data. Scientists interpret the empirical data by decontextualizing and re-contextualizing it, and in so doing arrive at new ideas; (iii) It is a kind of operation which suggests a statement in no wise contained in the data from which it sets out. Deduction: (i)

The single case in question is subordinated to an already known rule. Here a tried and trusted order is applied to the new case; (ii) Deductions are tautological, they tell us nothing new; (iii) They are also truth conveying: if the rule offered for application is valid, then the result of application of the rule is also valid.

8.2.4 Protocol

Following the Reichertz' protocol, this research adopted the following steps to develop the qualitative content analysis to the three Focus Groups:

1. Deciding on a research question. They are the sequence of questions of focus groups.

2. Selecting material. They are the primary data resulting of answers of participants of three focus groups.

3. Building a coding frame. Building a coding frame consists of the following steps: selecting material; structuring and generating categories; defining categories; revising and expanding the frame. A coding frame consists of at least one main category and at least two subcategories. Main categories are those aspects of the material about which the researcher would like more information, and subcategories specify what is said in the material with respect to these main categories. These steps can be carried out in a concept-driven or in a data-driven way. One way to do this is to create main categories in a concept-driven way and to add subcategories in a data-driven way. Working in a concept-driven way means basing the categories on previous knowledge (e.g. a theory, prior research, everyday knowledge, logic, or an interview guide). When working in a data-driven the most important strategies are: subsumption, sucessive summarizing and contrasting.

Subsumption is a useful strategy for generating subcategories in a data-driven way once main categories have been decided upon. It involves examining the following steps: (i) Reading the material until a relevant concept is encountered; (ii) Checking whether a subcategory that covers this concept has already been created; (iii) If so, mentally 'subsuming' this under the respective subcategory. If not, creating a new subcategory that covers this concept; (iv) Continuing to read until the next relevant concept/passage is encountered; (v) This process is continued until a point of saturation is reached; that is, until no additional new concepts can be found.

Successive summarizing involves paraphrasing relevant passages, deleting from these passages anything that appears superfluous, and summarizing similar paraphrases which are then turned into categories and subcategories. Comparing and contrasting is another strategy for developing entire coding frames in a data-driven way. This is especially useful for comparing different sources of data.

4. Segmentation. Segmentation involves dividing the material into units in such a way that each unit fits into exactly one category/sub category of the coding frame. Segmentation is in closely related to developing the coding frame and meeting the requirement of mutual exclusiveness. The size of segments or units should be chosen so as to match the definition of the categories.

5. The pilot phase. The pilot phase consists of the following steps: selecting material; the trial coding; evaluating and modifying the coding frame. The trial coding, is at the heart of the pilot phase. The categories from the coding frame are applied to the material during two rounds of coding, following the same procedure that will be used during the main coding. This can be done by two coders working independently of each other or else by one person coding and recoding the material within approximately 10 to 14 days. In this sense, the second strategy was the adopted to this study.

6. Evaluating and modifying the coding frame. Involves examining the results of the trial coding in terms of consistency and validity. First, on the consistency, if the definitions of subcategories are clear and straightforward and if the subcategories are mutually exclusive, units of coding will usually be assigned to the same subcategories during both rounds of coding. In other words, the higher the consistency between the two rounds of coding, the higher the quality of the coding frame. The second criterion for evaluating coding frames is validity. It is the extent to which the categories adequately describe the material and the concepts that are part of the research question. The distribution of coding frequencies across the subcategories for a main category is indicative of validity.

7. Main analysis. All material is coded and the coding frame can no longer be modified at this stage. The results of the main coding are entered into a coding sheet. In a final step of the main analysis phase, the results of coding should be prepared so that they are suitable for answering the research question.

8. Presenting and interpreting the findings. This can be done through continuous text or tables. The findings serve as a starting point for further data exploration, examining the results of qualitative content analysis for patterns and co-occurrences of selected categories.

The conduction of each focus group was made by the moderator (the author of this study) following a Discussion Guide (Appendix I, J, K). A person responsible to technical support (audio/video) also was mobilized to the sessions. A presentation in Power Point format including format with the main definitions, terminologies, and the respective sequence of questions also was used during each of each Focus Group. In this Discussion Guide the questions or topics were placed in an order to make sense for the participants and the flow of the discussion. A discussion guide should follow a funnel design, whereby the discussion flows from broad, general issues to more specific and focussed issues (Hennink, 2007). The following definitions and criteria noted by Hennink (2007) were considered to elaborate the questions of three Focus Groups:

Opening questions: The opening question(s) act as 'ice-breakers' to make participants feel at ease in the group situation. The first question is usually a brief factual question about the respondent themselves, as the purpose is to gain a short response from each participant.

Introductory questions: The introductory questions begin with general 'warm-up' questions followed by questions that introduce participants to the broad area of the research topic. The purpose of these questions is to make participants feel at ease in the group setting and begin to focus participants' attention on the research issues in a broad sense. Introductory questions are typically open-ended questions, with probing and follow-up by the moderator to gain detailed responses and to encourage participants to respond to the comments of others.

Transition questions: Transition questions move the discussion from the introductory stage towards the key issues of central interest to the research.

Key questions: Key questions are those that are directly related to the research problem. They are the most critical part of the discussion guide and contain the essential questions which must be asked of participants in order to answer the research questions. The information gained from the key questions will be analysed in the greatest depth. The key questions may be a series of individual questions or two to three topic areas each containing a series of questions.

Ending questions: Ending questions begin to bring the discussion to a close. Although the most critical issues will have been covered in the key questions, ending questions are also important as they can provide the moderator with a sense of the relative importance of issues raised.

Summary question: Involves the moderator making a short (two to three minute) summary of the major themes discussed in the group, and then asking participants whether this was an adequate summary of the issues, and if any issues were missed or misinterpreted.

8.3 Results

8.3.1 Focus Group 1

8.3.1.1 Objectives and target participants

As with all scientific research, the first tasks in planning Focus Group research involve clarifying the purpose of the study, defining the target population and considering the utilisation of the research findings (Hennink, 2007).

The essential purpose of this Focus Group is, from the perspective of specialists' background, to define the most suitable stages, tasks, tools for the life cycle of the PSS design (BOL, MOL, EOL) adapted to the manufacturing SMEs. The discussion was realized having as bottom line the first version (M1) of eco-innovation-oriented method to supporting SPSS design proposals in manufacturing SMEs. This version (M1) was elaborate from study conducted by Cavalieri and Pezzotta (2012).

Beginning Of Life

Phase of PSS	Tasks
1.Requirements generation	1.1 Strategic analysis of market. 1.2 Identification of the actors involved 1.3 Exploring market opportunities 1.4 Identify the value proposition to customer
2.Requirements identification	2.1. Customer demands identification 2.2. Describing and define the value proposition to the customer 2.3 Define requirements for the PSS
3.Requirements analysis	3.1. PSS idea development
4. Concept generation	4.1. Generation of concept.
5. Concept evaluation	5.1. Evaluation of concept
6.Concept development and evaluation	6.1. PSS concept development. 6.2. Definition and graphical representation of PSS structure, layers, interfaces and subsystems
7.Embodiment design and evaluation	7.1. Realize the integration of subsystems
8. Detailed design	8.1 Modelling of PSS
9.Test(prototyping or simulating)	9.1 PSS test 9.2. Evaluation of value proposition to customer
10. Final design	10.1. To improve the PSS design 10.2 Validation and Definition of concept 10.3 Define the performance measure system
11. Implementation and measure	11.1 Implementation of PSS 11.2 Measure performance

Midle Of Life

Phase of PSS	Tasks
12. Use and maintenance	12.1 Apply maintenance and recovery strategies
13. Monitoring and evaluation	13.1 Monitoring and evaluation of measure system of PSS

End Of Life

Phase of PSS	Tasks
14. End of life support	14.1. Actions to disposal, recycle, reuse etc
15.Monitoring and feedback analysis	15.1 Continuous improvement actions

Fig. 1. Version M1 of method proposed

From results of a systematic review study, the analysis of the most renowned Service Engineering process models was provide by Cavalieri and Pezzotta (2012). As result, an extensive list of phases along the life cycle has been elicited by merging the single proposals. Their findings permitted to infer that the most relevant phases investigated by these models are mainly related to the Beginning of Life with a great emphasis on all the requirement activities. Phases, such as Use, Maintenance and End of Life, have been considered only by recent publications, showing their increasing relevance in the development process.

They also found that another significant part of the literature has provided contributions on “How” the process phases and related tasks have to be carried out through the adoption of appropriate practices, in terms of methods and tools required to perform the single activities and phases.

Corroborating the relevance of this research as a whole, and also of this focus group, Cavalieri and Pezzotta (2012) also found that only a few methods have been developed specifically for service and PSS design, development and engineering. The most adopted methods derive from traditional engineering, business and computer science disciplines. They found that the literature have tried to systematise the different available methods aiming to elaborate a normative model and to give a complete view on how the different phases of the engineering process can be carried out, by the usage of an appropriate set of methods and tools. Particularly, none of them are oriented to manufacturing SMEs or are embedded in the eco-innovation perspective.

Hence, considering this proposal (M1), of the specific objectives of this focus group, from specialist' point of view, were:

- Discussed if all phases and sub-phases included in M1 are necessary to the life cycle of PSS design to SMEs context.
- Define if some phase may be included, excluded or modified in order to successful support the PSS design to SMEs context.
- Discussed if all activities and tasks included in M1 are necessary to the life cycle of PSS design to SMEs context.
- Define if some activity or task may be included, excluded or modified in order to successful support the PSS design to SMEs context.
- Define engineering/management tools more suitable to support and develop each activities/tasks or set of activities to successful support the PSS design to SMEs context.
- Define what are the mains interactions between actors x phases in M1 able to improve the value addition to customers.

To achieve these previous objectives the target population of the research needs to be clearly defined (Hennink, 2007). Hence, the participants profile is presented (Table 2).

Table 2: Participants of Focus Group 1

Specialist	Academic Background	Position	Research Focus	PSS Background
E1	PhD in Industrial Engineering in PSSs field. M.Sc. in Industrial Engineering.	Associate Professor.	PSS transition	Experience in research in PSS and in manufacturing SMEs by 3 years.
E2	Post-doc in Industrial Engineering and PhD in Industrial Engineering. Both in PSS field. M.Sc. in Industrial Engineering. Thesis developed in servitization.	Adjunct Professor. Researcher in sustainable PSS.	Customer experience in PSS	Experience in research on PSS and in manufacturing SMEs by 5,5 years.

E3	Post-doc in Industrial Engineering. PhD in Industrial Engineering. M.Sc. in Industrial Engineering.	Researcher. Adjunct Professor.	PSS transition and typology	Experience in research in PSS and in manufacturing SMEs by 4 years.
E4	Post-doc in in Industrial Engineering. PhD in Industrial Engineering. M.Sc. in Industrial Engineering.	Head of research group in PSS.	PSS transition	Experience in research and teaching in PSS and in manufacturing SMEs and large companies by 5 years.
E5	PhD in Industrial Engineering. M.Sc. in Industrial Engineering.	Researcher. Associate Professor.	PSS transition	Experience in research and teaching in PSS and in manufacturing large companies by 2 years.
E6	PhD student in Industrial Engineering in PSS field. M.Sc. in Industrial Engineering.	Researcher.	PSS transition	Experience in research and teaching in PSS and in large manufacturing companies by 3 years.
E7	Post-doc in Industrial Engineering. PhD in Industrial Engineering. M.Sc. in Industrial Engineering.	Researcher. Associate Professor. Member of International Society for Development & Sustainability	PSS transition	Experience in research and teaching in PSS and in manufacturing SMEs and large companies by 6 years.
E8	PhD student in Industrial Engineering in PSS field. M.Sc. in Industrial Engineering.	Researcher.	PSS design	Experience in research in PSS and in large companies.

8.3.1.2 Coding and Research Outcomes

Table 2 evidenced clearly that the composition of participants was defined to designing the appropriate discussion questions according to the objectives of this work. The post-field work activities of each Focus Group included the data preparation, analysis, coding (Table 3) and interpretation of the inputs. The findings to each round of questions of Focus Group are then discussed as follow.

Table 3: Coding and categories

Coding	Categories	Subcategories	Source in Focus group
1_PSS	PSS	Importance of PSS	Opening questions
2_PSS	PSS	Learning working with PSS	
3_PSS models	PSS models	Specific characteristics of PSS models for SMEs	Introductory questions
4_PSS models	PSS models	Determinants factors to successful PSS models for SMEs	
5_Reference models	PSS Reference models	Reference method to PSS model design for SMEs	Transition questions
6_Necessary phases	Necessary phases to PSS design in SMEs	Necessary phases along the life cycle of PSS design to SMEs	Key questions
7_ Necessary tasks	Necessary tasks to PSS design in SMEs	Necessary tasks along the life cycle of PSS design to SMEs	
8_ Necessary	Necessary tools to PSS design in SMEs	Necessary tools along the life cycle of PSS design to SMEs	

tools			
9_Interactions	Mains interactions to PSS design in SMEs	Mains interactions between actors x phases of PSS design to SMEs	
10_Architecture	The macro level organization and architecture of method	The relevant characteristics in the macro level of organization of development and the architecture of method	
11_Critical aspects	Critical aspects to PSS design in SMEs	More relevant points along the life cycle for successful PSS design in SMEs	Ending questions

The main criteria adopted to include and present the findings to all question in all focus groups are the coding frequencies across the subcategories. Reichertz (2014) stated that this frequency is a relevant indicative of validity of results. In the opening questions the participants introduced themselves and explained about their academic experiences and learning in PSS field and their opinion regarding to the importance of PSSs. The results (Table 4) reinforced previous findings in this research.

Table 4: Main outcomes to the opening questions

Code	Main Outcomes	Source
1_PSS	The PSS is very important because today the companies do not develop more products or services separately for a customer, but an integrated solution. And this solution may be bit or more tangible.	E6, E8
	The automotive companies that historically has been defined the concepts of Industrial Engineering have turned to the service market and to the collaborative economy marking a great market trend. All manufacturing companies tend to look at this process of servicing the economy.	E4
	The importance of services has been increasing for the economy as a whole.	All
2_PSS	The servitization can be a way to get into a PSS solution. The paths to the servitization are basically two: driven by customer demand or when the company wants to add value by adding services.	E5
	Based in my experienced, for the combined development of product and services, the initial and final phases of this process generally occur in an integrated manner. While in the middle stage, to the development it is necessary to distinguish between products and services steps.	E1
	PSS is associated with dematerialization. Service research communities generally are more focused on economic aspects, while PSS communities are more focused on sustainability and eco-innovation.	E1, E2, E5, E6, E7

The first finding corroborated is related with the distinction between the focus of servitization and the focus of PSS. Similar results were found in the research paper 3. Moreover, considering the importance of services for the economy as a whole, and also the role of SMEs to global economy, gradually add value by servitization initiatives might be the most correct decision to SMEs context. The SME may develop this aspect exploring customers' demands initially, or even developing new models adding service features the available products.

In the Introductory and probing questions the participants were questioned regarding: In which aspects the design of PSS models in SMEs differ and is similar in comparison to large companies? And what are the key determinants aspects of success in the design and implementation of PSS in SMEs?

The results regarding to the aspects in which the design of PSS models in SMEs differ and is similar in comparison to large companies are the following allowed to highlight several factors that were incorporated in the M2 version of the method.

Table 5: Main outcomes to the introductory questions

Code	Outcomes	Source
3_PSS models	The SME has a lower degree of formalization to offer a new business model such as the PSS.	E3, E7, E8
	The SME's flexibility allows it to position itself along the chain more dynamically. While in large enterprise the establishment of a new business unit to meet a PSS offer may be slower due to the amount of external channels and internal areas involved.	E2, E3, E7
	By partnering with other companies the SMEs can see new innovative business proposals for PSS offer. While large companies use strategy to buy smaller companies, making it difficult to position new product.	E5
4_PSS models	The SME also has greater flexibility and mobility by facilitating customer contact to capture needs and capture needed value for the PSS offer.	E2, E6, E7
	The analysis of the value chain in which the company is inserted helps to identify ways of adding sustainable value	E7
	In my previous researches carried out in SMEs, meeting the competitive criteria demanded by the client, was the most important aspect.	E1
	The product customization and a closer contact with customers is a facilitator for SMEs to develop PSS. The SME could perform a diagnosis of its service level before and compare after the implementation of the PSS offer.	E6
	The PSS design model needs to be simplified for SMEs. This improves the understanding.	E4
	The analysis of the value chain in which the company is inserted helps to identify ways of adding sustainable value.	E7

E4 also complemented highlighting that:

> "My impression is that the small business needs a much simpler and faster design model to respond to the market when compared to a large company. This is because a large company has a structure of functional areas and teams and integration of people capable of realizing the value offer. The SME when thinking about the service

> solution will prioritize the financial impact and not so much on the information needed to elaborate the offer. The same person in the SME will perform several stages of the service design model. That is why the model needs to be simplified (E4)”.

The summary of these results permitted evidenced implications to this study. First, the low degree of formalization of SME and need of the model be simplified suggested that the method must by simple and at the same time organized in a systematic stages. Second, explore the product customization, its flexibility, the closest contacts with customers to leverage new offers, and evaluation of the position of the SME in the value chain are relevant opportunities to be considered.

In the next step a main set of questions was proposed. A set of questions was organized according to the following subcategories: the necessary phases along the life cycle of PSS design to SMEs context, the activities and tasks to successful support the PSS design, the most suited engineering or management tools to realize each activity, task or even a set of activities/tasks, the mains interactions between “actors x phases” and finally the main input and output between the actors and phases (Table 3). The main findings, after content analysis of results, the each coding is detailed (Table 6-10).

Table 6: Main outcomes to the coding 6_Necessary phases

Outcomes	**Source**	**Objective**
Reverse the order of steps 12 and 13. Reduce the scope of steps 3, 4, and 5. Exclude step 10. The SPSS design method becomes more effective if you have product-specific and service-specific steps, and show the interfaces between product And services of these steps.	E4	Change or Exclude
Simplify and reduce the number of phases.	E3	
Insert steps to identify and validate business opportunities at the beginning and end of the method.	E1, E6	Insert
Insert a zero step of identifying business opportunities.	E4	
Insert a step to assess the impact on the three dimensions of sustainability	E2	
Provide a stage where the SME will seek partners to design the network necessary to elaborate the value proposition.	E4, E5	
Mentoring and external support giving an external look, such as consulting or government support bodies are beneficial as they provide the skills of the SME.	E2, E3, E7	
Consider a stage of analysis if the SME has the necessary skills to offer the PSS or if it needs to seek partners to fill the necessary skills.	E4, E5	
Generally the MOL step is underutilized in the PSS design templates. Given that in the PSS it is desired to increase the interaction time with the client, if the company is already established, it is indicated to start	E6	Explore

by the MOL of the method to propose new value offer.		

These results show several opportunities to improve the M1. The experts made several suggestions to further analysis by the moderator. An interesting factor cited by E6 on the underutilization of step MOL in PSS models available from literature, also is cited by Cavalieri and Pezzotta (2012) and Yang et al. (2017). Value uncaptured in MOL has rarely been investigated by researchers and practitioners.

This implies a gap in this research field (Yang et al., 2017). The gap of competences noted by the experts also was found in the previous results of this research (see Chapter 1, 2, 4). A possible strategy to minimize this effect pass by organizes the method in a simplified manner and adopting a systematic architecture of activities.

The next coding describes the results of content analysis regarding to necessary tasks.

Table 7: Main outcomes to the coding 7_Necessary tasks

Outcomes	Source
Perform the product life cycle analysis at the beginning and end of the PSS design proposition.	E3
Consider the end of product life by adopting 3Rs logic, crade-to-cradle, reverse logistics etc. at some stage of the method.	E2, E7
Have a sponsor or leader responsible for the PSS.	E1
The enterprises focused on meeting customer demands are more open. Therefore, it is necessary for SME to understand its resources and available skills to evaluate if it can meet the offer.	E4, E5
Insert analysis of the impact of sustainability and social impact.	E2, E4

These results demonstrate the need of insert two major topics in a further version of method: the life cycle analysis oriented to the sustainability and the mapping of competences and resources available in the SME during the stage of selection of the value propositions.

The next coding describes the results of content analysis regarding to possible tools to consider in the method.

Table 8: Main outcomes to the coding 8_Necessary tools

Outcomes	Source	Type
Design Think tools and Business Model Canvas help in the initial stage of defining and identifying opportunities.	E3, E5, E6	Design Thinking
One of the great advantages of Design Thinking is to provide agility in launching the service to the market.	E6	
Design Thinking is exceptional for innovation and not so deployment-oriented.	E3	
To identify requirements make the analysis of Customer Journey Map.	E8	
Use Canvas Value Proposition and Business Model Canvas because are simple tools.	E5	
Use the Personas tool as output / result of the requirement stage and definition of the key customers. In the concept phase of PSS use Blueprint.	E3, E8	
Perform the value chain analysis at the beginning of the application of method.	E7	Engineering
Using multicriterial analysis (e.g. Maut) to select the services that will be included in the value proposition is a possibility.	E4	
Use Technology Road Mapping (TRM) to generate technical evolution and represent tacit knowledge.	E1, E6	
Use the QFD quality matrix to identify metrics and trade-offs between customer requirements.	E3	
Apply simulation of services using Lego Serious Play, simulation software and etc. Use Lego serious play for prototyping and evaluate the interaction interfaces of the value proposition.	E2	Simulation
Use Virtual Reality or Role Plan for prototyping. Can also be used to define requirements.	E1, E7, E8	
Bring examples of application of the tools suggested in the model to help SME to understand the operationalization of each tool.	E1, E6	Architecture
Instead of indicating tools in the steps, suggest tools according to purpose. Give examples and tool options for each step.	E7	

The validity of content analysis results on tools is reinforced by several findings obtained from literature. For example, as well as the experts opinion indicated the use of the Design Thinking tools as being more suited to needs and characteristics of SMEs, previous studies (Orloff and Heinz, 2015; Xing and Ness, 2016; West and Nardo, 2016) have been found the advantages of service design tool kit to PSS design in SMEs. These propositions based in the advantages of the Design Thinking tools also are aligned with previous results of this Focus Group (Table 5), where the specialist reinforce that the method must be simplified and easy to use.

Furthermore, the findings suggested well-consolidated engineering tools and recent simulation tools. Particularly, a relevant insight of this stage was the concern with capacity of comprehension of SMEs and the responsible employees to apply the tools of proposed method. Hence, the use of examples of application of the tools and present options of tools to realize the tasks may be a good strategy.

The following coding describes the results of content analysis regarding to interactions along the life cycle of a PSS. In this sense, the summaries of insights extracted from the content analyses are presented:

Table 9: Main outcomes to the coding 9_Interactions

Outcomes	Source
The MOL phase is underutilized in the PSS literature. This phase results in customer interaction and behaviour and needs to be explored to generate new value propositions or to perfect the current proposal. It was suggested to broaden and detail this phase in order to improve the value proposition or create new ones, as well as to evaluate if the sustainable and social benefits are being maintained.	E3, E3, E6
The value creation in services occurs in MOL whereas Value creation in products occurs in BOL.	E6
The SME should have an approximation with Fablabs to carry out the prototyping. The interaction between SME and its partners and stakeholders aligned with sustainability is a critical interaction to consider.	E7
Interaction between the front office employees of the service/enterprise and the customer is a critical interaction to consider.	E8
The interaction between SMEs with technology centers, universities, and current legislation is a critical interaction to consider.	E2

The validity of results obtained in this category with the consensus of some specialists also is corroborating by findings from literature. Aligned with this assumption, Cavalieri and Pezzotta (2012), for instance, also found that phases such as Use and Maintenance in MOL, and also the End of Life phase, have been considered only by recent publications, showing their increasing relevance in the development process.

Another interesting insight from content analyses is regarding to Fablabs. In fact, explore the possibilities and the environment of a Fablab might speed up the process of validation/prototyping, or even of conceptualization activities during the development of value proposition. In this sense, is expected that the SMEs adopt proactive-behaviour in in order to get closer of Fablabs. Besides, as additional benefit, the dualistic process of chance experiences versus demand may improve the competences of SMEs in innovation issues. On the other hand, by analyse of outcomes, it is possible affirm that all the critical interactions cited by experts are complex as to the management and the consideration in the scope of a design method.

Table 10: Main outcomes to the coding 10_Architecture

Outcomes	Source	Attributes
This proposal of the method seems to be more suitable for product-oriented PSS and for well established companies that want to aggregate services to products and not new ones like the start-ups.	E4, E5	Scope
It is difficult to contemplate in the scope of a model the different aspects of the research groups existing in PSS and servitization. Such as for example, the different approaches given to this theme between the groups from UK versus Italy versus DK.	E4	
Analyze whether the corporate network governance model can contribute to the proposed method, based on the stakeholder logic used in this field of research.	E3	Network and partner
For the PSS design the SME needs a model, roadmap or simplified guide.	E4, E5	Simplified
Thinking about the lack of time and resources of SMEs, the diagnosis could be more detailed and structured, but the whole method needs to be less detailed.	E1	
The method should be simple.	E2, E8	
May exist resistance of SMEs regarding to the name and meaning of the expression “PSS”. The SMEs can reject for not knowing. So the importance of using more soft terms in the method architecture.	E1, E6	Terminology
Use simpler terms to name of steps along the proposed method.	E2	
To be generalist and guarantee the specificities of each case, the method should allow for more horizontal detailing of the phases and not be as vertical.	E6	Structure
The method needs to be agile and should allow rapid prototyping of the chosen PSS.	E2, E5, E7	
The method should show the benefits to the customer and the financial return as a priority.		

Agreeing with the findings obtained in previous categories, the insights obtained here reinforce some aspects already discussed. The first is related whit the simplicity and agility of structure of artefact, which include, for example, the use of simple language along the steps of method. The second is regarding of SME looking for partnership to stablishes the mobilization and orchestration of value proposition to attend the PSS offer. This can occur by different manners: according to the position of SMEs in the supply chain in which its operate, by the association of SME with other SMEs, suppliers among others. Finally, the during the content analyses process, was possible establish a new subcategory of attributes that may be analysed as input information to develop the improved version of method (M2).

8.3.2 Focus Group 2

8.3.2.1 Objectives and target participants

This second focus group adopted the study by Yang et al. (2014; 2017) as bottom line for discussion. Recent research and practice show that business model innovation, as is a SPSS offer, is a promising approach for improving sustainability in manufacturing firms (Yang et al., 2017).

The main reasons in order to use this study (Yang et al., 2014; 2017) as reference to this focus group are the following. First, these studies are focused specifically on the generation of innovative value proposition for sustainable business model innovation and specifically in PSS. As well as, is the proposed of our research aiming develop an eco-innovation-oriented method in SPSS. These studies were conducted by researchers belonging of the recognized Institute for Manufacturing from Department of Engineering in the University of Cambridge, UK. It is a well-recognized research group in PSS and sustainability fields. Second, our research seeks advance beyond of the well-consolidate concept of value proposition discussed in PSS literature. Hence, both goals are aligned because this thesis aim gives a new perspective to the innovation process in the PSS literature adopting a new concept of value proposition to the PSS life cycle analysis. Considering the concept of "value uncaptured" as was defined by Yang et al. (2017) this thesis proposed an extension of this the concept defining as "sustainable value uncaptured". To this thesis this new proposed concept can be defined as:

*"**Sustainable Value Uncaptured** is the set of economic, social and environmental benefits that could be captured but have not yet been captured by the enterprise and may be incorporating in a new or in an existent SPSS offer".*

Third, they propose value uncaptured as a new perspective for sustainable business model innovation, and developed four forms of value uncaptured: value surplus, value absence, value missed and value destroyed. Fourth, these new concepts of value in PSS are oriented to the three dimensions of sustainability. This assumption is aligned with the eco-innovation concept and the goals of this thesis. Fifth, this study corroborate previous findings in our research (see Chapter 1, 2 and 4), in which was found that there is a need for a more comprehensive understanding of value in order to promote sustainability in PSS business models to SMEs.

The identification of sustainable value uncaptured along the PSS design in SMEs has potential to trigger the discovery of new value opportunities, which led to innovation of the business model. The novelty of this perspective to this thesis is to use negative forms of value to stimulate the identification of negative aspects of the current business model and trigger the eco-innovation of positive business models extending the proposition by Yang et al. (2017).

Before advance in the results of this Focus Group, the main definitions discussed during the Focus Group are then presented, according to Yang et al. (2017) stated:

Value. Value is defined, in a Value Management (VM) context, as the relationship between the satisfaction of needs and the resources used in achieving that satisfaction.

Value Captured. Value captured in literature is defined as 'how the firm generates revenue and profit' and it includes 'revenue sources' and 'the economics of the business'.

Value Uncaptured (VU). Value uncaptured is the set of benefits that could be captured but have not yet been captured. Value uncaptured is not only for customers and the firms, but for all stakeholders, such as end users, suppliers, shareholders, government and partners. Secondly, the value covers not only monetary value, but also wider value for the environment and for society. In this sense, the four forms of value uncaptured applied to sustainable PSS business models are: value surplus, value absence, value missed and value destroyed.

Value Surplus (VS). Value Surplus is value which exists, but is not required. These are things or activities that are more than needed. They are redundant and unnecessary. They can be regarded as waste in a company or unnecessary value delivered to stakeholders. The concept of VS is similar to waste but embodies a broader meaning. It includes not only tangible waste but also intangible waste, such as underutilisation of human resource. It offers higher potential to be turned into value. It exposes avoidable resource consumption and cost. Examples could be wasted heat, waste energy, over production, underutilisation of resources, and unnecessary, repeated work.

Value Absence (VA). Value Absence is value which is required, but does not exist. They are things or activities that are needed but have not been provided. It can be regarded as needs that could have been met but have not yet been met; or as a lack of resource that is needed by the company or its stakeholders. For example this could be a temporary lack of labour, the need for recycling service, the need for experts in certain fields, or the need for a platform. A specific example could be that there is a temporary need for additional warehouse space and workers due to increased production, but the company may not be inclined to buy extra warehouse space or to hire new employees just for this short busy period. In this case, the need for additional warehousing and labour can be regarded as a value absence.

Value Missed (VM). Value Missed is value which exists and is required, but is not exploited. It could create more value but it does not. It is currently squandered or inadequately captured by the current business model. It can be regarded as waste with high potential to be used. It does not bring about negative outcomes but it reduces value that could be created. Examples are underutilization of by-products and co-products, underutilised assets and resources, and inefficient use of human resources.

Value Destroyed (VD). Value Destroyed is value with negative outcomes. It causes negative effects for the company or other stakeholders, and is the negative outcome of the current business model. It can be seen as damage to the planet, people and profits. In the context of sustainability, value destroyed refers particularly to damage to the environment and to society. Examples include depletion of non-renewables, pollution, poor product and service quality, bad working conditions and health and safety problems.

Finally, these four source of value uncaptured may be identify by two sources: (i) Visible: for example, waste streams in production, co-products, under-utilized resources, and reusable components of broken products; (ii) Invisible: for example, over capacity of labour, insufficient use of expertise and knowledge.

As a consequence, the main objectives of this Focus Group aligned with the proposed of this thesis are:

- To extend the main categories of sources of value uncaptured and the detailed aspects across the PSS life cycle to manufacturing SMEs;
- To define strategies to increase the added value in each phase of PSS life cycle suited to manufacturing SMEs.

To achieve the objectives in a Focus Group the target participants of the research needs to be clearly defined (Hennink, 2007). Hence, the participants profile is presented (Table 11).

Table 11: Participants of Focus Group 1

Specialist	Academic Background	Position	Research Focus	PSS Background
E1	PhD in Industrial Engineering. M.Sc. in Industrial Engineering.	Head of research group in PSS. Full Professor.	PSS transition	Experience in research and teaching in PSS and in manufacturing SMEs and large companies by 8 years.
E2	PhD in Industrial Engineering. M.Sc. in Industrial Engineering	Full Professor.	PSS transition	Experience in research in PSS and in manufacturing SMEs and large companies by 4 years.
E3	PhD student in Industrial Engineering in PSS field. M.Sc. in Industrial Engineering.	Researcher.	PSS transition	Experience in research and teaching in PSS and in large manufacturing companies by 2 years.
E4	PhD student in Industrial Engineering in PSS field. M.Sc. in Industrial Engineering.	Researcher.	PSS transition	Experience in research and teaching in PSS and in large manufacturing companies by 3 years.
E5	PhD in Industrial Engineering in PSS field. M.Sc. in Industrial Engineering.	Researcher.	PSS design	Experience in research and teaching in PSS and in large manufacturing companies by 5 years.

8.3.2.2 Coding and Research Outcomes

According to the protocol adopted, each specialist received with antecedence a document with the preparation guidelines and conceptual definitions used in the discussion. The post-field work activities of each Focus Group included the data preparation, analysis, coding (Table 12) and interpretation of the inputs. The findings to each round of questions are then discussed as follow.

Table 12: Coding and categories

Coding	Categories	Subcategories	Source in Focus group
1_Factors	Critical Factors	Critical factors to capture Sustainable VU (economic, environmental and social) in manufacturing SMEs.	Opening questions
2_Actions and tools	Increase the value proposition	Actions and strategies to increase the sustainable value proposition (economic, environmental and social) in manufacturing SMEs.	Introductory questions
3_Stages	PSS life cycle	Stages of the PSS life cycle have greater potential to generate Sustainable VU (economic, environmental and social) in manufacturing SMEs.	
4_New sources	New responsive and agile sources of VU	New responsive and agile sources of Sustainable VU (economic, environmental and social) along the PSS life cycle in manufacturing SMEs.	Key questions
5_ New aspects	New responsive and agile aspects of VU	New responsive and agile aspects of Sustainable VU (economic, environmental and social) along the PSS life cycle in manufacturing SMEs	
6_New activities	New responsive and agile activities of VU	New responsive and agile activities of Sustainable VU (economic, environmental and social) along the PSS life cycle in manufacturing SMEs	
7_Tools	Engineering or Management tools	Engineering or Management tools to leverage the value addition (economic, environmental and social) and able to unlock the Sustainable VU (economic, environmental and social).	
8_Critical sources and tools	Critical sources and tools of Sustainable VU	Highlighted critical sources and tools of Sustainable VU	Ending question

During the coding process the main criteria adopted to include and to exhibit the findings was based the occurrence of patterns and co-occurrences of selected categories (Reichertz, 2014). In the opening question the participants introduced themselves and answered what are the critical factors that the SME should consider to capture sustainable VU (economic, environmental and social) and add value to the customers considering the actors and stakeholders involved in the PSS business model. The intend of this discussion is represented (Fig. 2). The results of qualitative content analysis (Table 13) reinforced previous findings.

Table 13: Main outcomes to the coding 1_Factors

Code	Main Outcomes	Source
	SME managers need to know in loco how their product is used by the customer to understand customers' pains and improve the value proposition.	E1, E3, E4

1_Factors	Establish partnerships with other companies to minimize skill gaps and offer complete value propositions.	E1, E3
	Qualification of the management of decision makers and owners of SMEs. Limitation of technological infrastructure and access to technology and investments is a blocking factor.	E2
	Regarding market positioning, the SME should focus on alternative market niches instead of competing in the large companies market. SMEs should prioritize disruptive innovations.	E3, E4

The specialist E1 still complements stating that:

> "I realize that, while some SMEs offer excessive value and badly others SMEs offer less value than expected leading to customer dissatisfaction whether in a B2B or in B2C environment. Although SMEs are generally closer to the customers, they are limited by the company's owner's view, especially in family businesses, with the owner's paradigm that: "I founded the company and that product and the market must fit to my product." In segments of low technological intensity (e.g. furniture factory) this is more present (E1)."

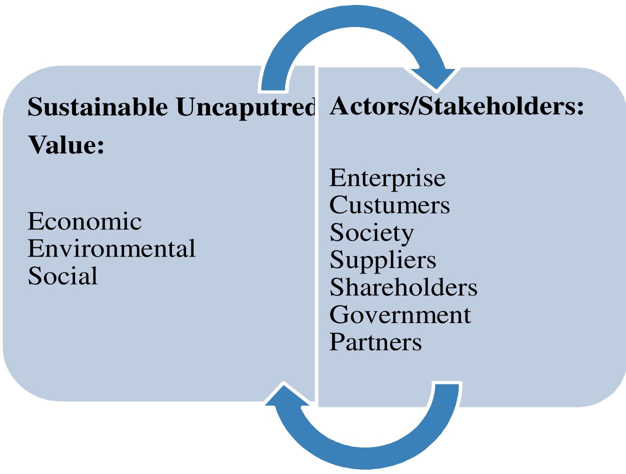

Fig.2. Interaction flow to capture Sustainable VU.

In sum, the results demonstrate fundamentally factors associate with comprehend customer' needs, the relevance of partnerships, and in structural characteristics of SME such as access to external founds and profile of owner. Based in this findings is possible a infer that the clear understanding of customer' needs associate with strategic partnerships will enable a best market positioning or even disruptive innovations oriented to integrate solutions in a PSS.

The following category discussed the actions, strategies and supporting tools in order to increase the sustainable value proposition (economic, environmental and social) in manufacturing SMEs.

Table 14: Main outcomes to the coding 2_Actions and tools

Code	Main Outcomes	Source
2_Actions and tools	The SME must clearly understand its position within the supply chain and its strategic positioning and from this to identify its niche of action.	E1, E3, E4
	It is necessary to clearly understand the competitive dimensions required by the market in which it operates. This will define and mark out the whole value proposition.	E1
	As higher is the percentage of services contained in the value proposal or then in business environments with performance-based measurement, the greater care needs to be taken by SME. Therefore, the SME's frontiers in its value chain and market must be clearly known and defined.	E1, E3, E4
	Value Proposition Canvas to identify the pains of the client and offer the solution.	E3
	Customer Value Chain Analysis (CVCA).	E4
	Benchmarking and technology mapping tools.	E1, E3, E4, E5

E3 still stressed that "[…] even large companies are afraid to service due to the risks and uncertainties of the business and difficulty in orchestrating the value proposition".

Reinforcing previous findings (Focus Group 1) E4 summarized saying that "[...] in general it is possible to say that the tool kit available in the PSS field is larger for the concept design stage and smaller for leveraging the MOL and EOL stages."

Regarding the stages of the PSS life cycle that have greater potential to generate Sustainable VU (economic, environmental and social) in manufacturing SMEs results were:

Table 15: Main outcomes to the coding 3_Stages

Code	Main Outcomes	Source
3_Stages	The greater the technological intensity and the greater adoption of information technologies using systems integrated in the business model, the opportunities to capture VU will be more in the BOL. On the contrary, the more product-oriented the company is, the VU opportunities will be more in MOL and EOL.	E1, E3, E4, E5
	The MOL and EOL steps are more propitious to transforming VU into captured value.	E4
	When the solution is pulled by the customer and requires more innovation the opportunities to transform VU into captured value will be in the BOL (e.g. start-up)	E3

E1 also underline that: "It is necessary to analyze the end of life of the PSS verified how it behaved during the useful life to identify new opportunities".

Aiming to extend the sources and also the aspects that could be explored within each category of source to result in generation of Sustainable VU (economic, environmental and social) found in Yang et al. (2017), a discussion was realized in the perspective of PSS life cycle for manufacturing SMEs. The main objective of this extension is the SME use this final framework as a reference or even as a verification list following the logic of a structured brainstorming along the SPSS design, supporting the generation of sustainable innovation in the MOL, BOL and EOL of method. As outcomes of qualitative content analyses, the set of sources of VU initially suggested by Yang et al. (2017) was extended and oriented to SME context. The additional sources that emerged from this Focus Group are highlighted in *italic* format (Table 16). However, it is necessary state that different types of value uncaptured probably will have variation of importance for different business models configuration of enterprises and the generalization always is a complex task.

Table 16: Results to the coding 4_New sources of Sustainable VU

BOL-VU	MOL-VU	EOL-VU
• Design • Production • Operations management • Customer needs • Human resources • Contracts *management* • R&D • Finance • Planning ✓ *Knowledge & technology* ✓ *Current legislation (e.g. environmental, taxes)* ✓ *Professionalization of top management* ✓ *Partnerships with companies inside and outside the chain* ✓ *Competitors* ✓ *Marketing opportunities* ✓ *Quality management process* ✓ *Explore Post-sales and Marketing area* ✓ *Innovation process* ✓ *New applications to the existing products* ✓ *Update of technologies* ✓ *Data base of enterprise (Business Analytics)* ✓ *Process and Project Management* ✓ *Geographic location*	• Customers' value uncaptured • Human resources • Operations management • Service data • Co-products or by-products • Products' products • Services • Customer needs • Need for a platform • Delivery • Conflicts over service contracts • Risks ✓ Wasted resources and energy ✓ *Customization of Services* ✓ *Modularization of Services* ✓ *Customer cultural aspects* ✓ *Interaction with business partners* ✓ *Contracts management (e.g. not monitor customer satisfaction, not comply with contract, do more than contractor not to lose customers)* ✓ *Big data and IoT to capture new value proposition* ✓ *Alternative source of energies* ✓ *Update of technologies* ✓ *Exploitation of resources idleness* ✓ *Update of technologies* ✓ *Data base of enterprise*	• Recycle • Reuse • Remanufacture ✓ *Social and environmental responsibility actions* ✓ *Sharing of resources (e.g. equipment, etc.)* ✓ *Post-sales as strategic articulator of new value propositions and sales* ✓ *Refurbish products* ✓ *Disposal* ✓ *Resale of products* ✓ *Accept old products as part of the payment to buy new product (e.g. Apple)*

	(Business Analytics) ✓ *Process and Project Management* ✓ *Geographic location* ✓ *Sharing of resources (e.g. equipment, etc.)*	

As main result of this stage, 36 new sources of Sustainable VU was extend added in the original list proposed in Yang et al. (2017). In the following key question the category discussed new responsive and agile aspects of Sustainable VU (economic, environmental and social) along the PSS life cycle in manufacturing SMEs. As result of qualitative content analyses, a set of complementary detailed aspects to explore each main source of VU was obtained. The full list suggested by Yang et al. (2017) was extended and oriented to SME context as indicated in italic format (Table 17, 18, 19).

Table 17: Results to the coding 5_New detailed aspects of Sustainable VU

BOL-VU	Aspects
Design	• Production • Operations management • Customer needs • Human resources • Contracts • R&D • Finance • Planning • Knowledge & technology ✓ *Legal aspects* ✓ *P+L tecnologies* ✓ *Ecodesign* ✓ *Trend market mapping* ✓ *User oriented design* ✓ *Design for X*
Production	• Over procurement or too early procurement • Poor production technology • The seven wastes from lean production • Pollution (e.g. noise) • Quality problems ✓ *Less Bureaucratic and data-driven oriented management* ✓ *Visual management* ✓ *Lack of technological structure* ✓ *Infrastructure (people, facilities)* ✓ *Co-production and sharing equipment* ✓ *Misalignment of measure system with the PSS results* ✓ *Qualification of the workforce*
Operations management	• Poor flexibility • Bad mechanism for assessing rewards and penalties • Bad project time management Inefficient inter-department collaboration and resource sharing • Poor execution ability • Insufficient use of information management systems • Reluctance to adopt new management systems

	• Unable to adapt to new technology and products • Inefficient workflow ✓ *Precisely know the capacity installed* ✓ *Scheduling and production control* ✓ *Performance metrics (Strategic, Tactic and Operational)* ✓ *Operate in cooperation networks* ✓ *Improper use of sales and distribution channels* ✓ *Share resources* ✓ *Obsolete technology* ✓ *Qualification of top management* ✓ *Lack of resources and budget*
Customer needs	• Unknown potential customers • Potential customer needs • Future customer needs • Unclear customer needs • Overpromising to meet customer needs ✓ *Evaluate the impact of legislation (on the products, processes, facilities)* ✓ *Lack of structured processes to capture value opportunities* ✓ *Unconventional customers*
Human resources	• Excess capacity of managers, designers, production workers • Lack of excellent human resources • Insufficient and inefficient use of workers ✓ *Turnover and escape ok knowledge* ✓ *Health and ergonomic aspects of employees of the front and back office* ✓ *Insufficient exploration of employers' competences and creativity*
Contract	• Low-profit contracts • Unclear service contracts ✓ *Lack of process to contract management* ✓ *Extra services not included in the contract* ✓ *Low reliability of contracts*
R&D	• Lack of R&D in basic scientific research • Lack of R&D into products' products • Lack of IP protection ✓ *Stimulus and investments to innovate* ✓ *Lack of capacity* ✓ *Lack of ability to perceive and then capture the value generated by R&D* ✓ *Unclear strategy of R&D* ✓ *R&D does not consider the technologies available in the company*
Finance	• High initial investment and low profits ✓ *Have a database of private/public sources to funding/investments* ✓ *Financial collection system does not support timely and long-term transactions* ✓ *The company's financial structure does not support instalments* ✓ *Low reliability in cash flow controls* ✓ *Decision-making process based on data*
Planning	• Unclear strategic plan ✓ *Absence of strategic plan*
Knowledge & technology	• Lack of knowledge and technologies • Wasted knowledge, technology, experience and skills ✓ *Lack of knowledge in services that that could be offered in new value propositions* ✓ *Partnerships with companies to share technological resources* ✓ *Mapping and selection of suited knowledge and technologies*

Table 18: Results to the coding 5_New detailed aspects of Sustainable VU

MOL-VU	Detailed Aspects
Customers' value uncaptured	• Customers' wasted resources • Customers' waste from products, co-products & by-products • Customers' unprofessional use of products • Customers' pollution • Customers' poor ability in identifying value uncaptured • Customers' missed applications for products • Insufficient communication between customers and manufacturers • Customers' production waste ✓ *Underutilization of the knowledge generated by the users of the product/service, to generate new offers* ✓ *Explore co-production and co-creation of offers with the customers*
Human resource	• Excess capacity of service workers • Insufficient and inefficient use of service workers • Lack of excellent human resources • Inefficient communication between workers • Repeated work ✓ *Lack of understanding by HR of the particularities of the services* ✓ *Clarity of information to the front-office employees* ✓ *Mapping skills of front-office employees* ✓ *Explore the use of creativity of front-office employees* ✓ *Health and ergonomic aspects of employees of the front and back office* ✓ *Turnover and escape ok knowledge*
Operations management	• Lack of regulations for operational management • Inefficient workflows (e.g. time, money and human resources wasted in workflows) • Service scheduling problems • Unnecessary waste in operations • Poor flexibility • Low operational efficiency • Poor mechanism for rewards and penalties • Poor execution ability • Inefficient inter-department collaboration and resource sharing • Inefficient communication between service workers, designers and producers ✓ *Network of partnerships is not well defined and aligned* ✓ *Monitor the contracts performance with customers or a group of customers* ✓ *Solidify the use of standards and procedures* ✓ *Sense of loss of power and empowerment of the manufacturing area with the increasing importance of the company's service area*
Service data	• Lack of technology, expertise and knowledge on using data • Inefficient and insufficient use of service data (done manually) • Missed value from historical service data relating to existing customers • Inefficient service arrangements • Limited access to some services ✓ *Difficulty connecting with customers' operating systems* ✓ *Compliance rules* ✓ *TI governance rules* ✓ *Explore data for new offers*
Co-products or by-products	• Insufficient use of co- and by-products • Unknown applications for co- and by- products • Unable to use co- and by- products ✓ *Opportunities to co-production* ✓ *Define mechanisms to control the partnerships*
Products' products	• Missed applications for products' products • Unknown applications for products' products
Service	• Excess service (e.g. unnecessary services, idle service workers, too much investment in service resources) • Poor service effectiveness and efficiency • Missed service opportunities • Lack of service experience • Service scheduling problems (e.g. who, when and how many workers to send)

	• Invalid services • No calculation, *pricing* and control of service cost • Poor service quality • Low service charges • Lost or missed business opportunities during service • Inefficient allocation of service personnel • Service tasks too detailed • Ineffective service evaluation system ✓ *Alignment of the proposed value with available resources* ✓ *Mapping strategic services* ✓ *Alignment of services with the PSS strategy* ✓ *Possibility of tailor-made services* ✓ *Lack of control/feedback of service execution (e.g. along front office, satisfaction survey, perceived quality survey)* ✓ *Unclear definition of the service and product portion of the PSS to ensure financial resilience with manageable risk.* ✓ *Sale and promotion process of the product/service in the market*
Services' Services	✓ *Identify additional services from current offer*
Customer needs	• Unknown customer needs (e.g. real needs, potential needs, hidden needs and future needs) • Inaccurate understanding of customer needs • Changes in customer needs • Unclear customer needs ✓ *Underutilization of new technologies (Big Data and IoT) to capture customer needs.* ✓ *Generation of new or future needs from the initial offer*
Need for a platform	• Need for a platform to sell the collected waste • Need for a platform to enter new industrial sectors ✓ *Define channels for use and reuse.* ✓ *Improve marketing channels* ✓ *Incompatibility with existing platforms*
Delivery	• Delays in delivery • Missing components in packaging • Sending wrong products or components • Late deliveries ✓ *Strategic alignment of sales and delivery channels* ✓ *Explore partnerships* ✓ *Collect information about the application context during the delivery*
Conflicts over service contracts	• Difficulty in judging responsibilities in relation to service contracts ✓ *Clear costs system in contracts* ✓ *Low customer engagement for a satisfactory operationalization of contract.*
Risks	• Market risks • Policy risks ✓ *Environmental risks* ✓ *Social risks* ✓ *Technological risks* ✓ *Changes in legislation* ✓ *Incorrect market positioning* ✓ *Observe governmental policies movements* ✓ *Unclear definition of risks in contracts*
Waste of resource and energy	• Waste of mechanical work • Waste of energy (e.g. electricity, heat, cold energy, hot water, cold water and steam) • Underutilised resources (e.g. underutilised assets) • Oil leaks • Lack of freedom to use all this waste since it needs agreement from the customer ✓ *Lack a system measure to waste of resource and energy*
Others	• Unexpected problems during service • Lost customer loyalty • Pressure from retailers ✓ *Share resources (e.g. equipment)* ✓ *Clarity on expected PSS deliveries* ✓ *Partnerships with clients* ✓ *Sub utilization of customers' loyalty*

Table 19: Results to the coding 5_New detailed aspects of Sustainable VU

EOL-VU	Aspects
Recycle	• No or little recycling • Lack of awareness and knowledge of recycling • Valuable materials in discarded products • Low-value disposal of recycled products • No customer demand for recycling • Lack of recycling guidance, *strategies* and methods ✓ *Lack of understanding of reverse channel and key actors* ✓ *Decision making without multicriteria analysis* ✓ *Low disclosure on the benefits (environmental, social, economic)*
Reuse	• Idle, usable, re-purchased old products • Insufficient use of usable old products • Usable products discarded by customers • Low-value disposal of usable products and components • Poor customer acceptance of reuse of products • Small market for used products ✓ *Lack ok of strategies to extend the life cycle of products* ✓ *Strategies for reuse of services* ✓ *Low use of design of disassembly* ✓ *Low disclosure on the benefits (environmental, social, economic)*
Remanufac-ture	• No or little remanufacturing • Lack of awareness and knowledge of remanufacturing • Lack of capacity to undertake remanufacturing • Need for low-cost remanufacturing technology • No customer demand for remanufacturing • Low acceptance by customer of remanufactured products • Lack of remanufacturing guidance and methods ✓ *Explore remanufacture to cut down on underutilized manufacturing resources* ✓ *Develop supply chain of remanufacture to the manufacturing activities* ✓ *Low disclosure on the benefits (environmental, social, economic)*
New value proposition to EOL products	✓ *Identify new business opportunities extending product life cycle* ✓ *Use EOL products as bottom line to new SPSS* ✓ *Explore aftersales area to identify new business opportunities*

According to the protocol adopted in this research to conduct the Focus Groups by Reichertz (2014), two main criteria indicative of validity were considered during this step of qualitative content analysis: the distribution of coding frequencies and the consistency. In a nutshell, from the analyses of results emerged two new categories of sources of Sustainable VU. The first was *"Services' Services"* (Table 18) applied in the MOL of life cycle. And the second source was "*New value proposition to EOL products"* (Table 19) applied in the EOL of life cycle. The respective detailed aspects to be explored within each one of new source also were revealed. Hence, to the new category "*New value proposition to EOL products"* three detailed aspects emerged: (i) Identify new business opportunities extending product life cycle; (ii) Use EOL products as bottom line to new SPSS; (iii) Explore aftersales area to identify new business opportunities. Finally, to the new source *"Services' Services"* one main aspect emerged: identify additional services from current offer. On the whole, to the BOL stage 45 new aspects were included, to the MOL, 48 and to EOL, 16 aspects.

The following category of focus group aimed explores possible new responsive and agile activities of Sustainable VU (economic, environmental and social) along the PSS life cycle in manufacturing SMEs. To perform this step (Table 20), the specialists were provoked to associate sources of sustainable VU according to the phases of the version M1 of method (Appendix E, Form 3). In the end of this process, the content analysis of this step was compared with the results obtained in the Focus Group 1.

Table 20: Results to the coding 6_New activities of Sustainable VU

Life Cycle	Phase of SPSS in M1	Main Outcomes	Source
BOL	Requirements generation	Verify the end of life of technologies used by the company and explore new technologies Non consider the legal demands Resources analyse (e.g. energy, water, raw material, suppliers partners) Explore expertise unknown but existing in the suppliers Explore opportunities to share resources with partners of PSS offer	E1
		Partnerships with competitors	E3
		Comprehend the employers' competences	E1, E4
		Requirements for the actors evolving in the PSS	E4
		Identify potentials new segments, customers and suppliers	E5
	Requirements identification	Latent and emergent customers' needs	E2
		Mapping extra benefits in social and environmental aspects	E3
	Concept generation	Explore design elements	E2
	Concept evaluation	Define operations evolving the PSS offer	E2
		Definition of measure system and critical control points	E2, E4, E5
	Concept development and evaluation	Flow of activities of PSS offer	E2
		Used technologies Evaluation of portion of Product and Service suited to the level of risk accept by SME	E3
	Detailed design	Systems and ICT to PSS offer	E2
	Test (prototyping or simulating)	Identify opportunities and Factors Critical Success of PSS offer	E2
	Final design	Cost system and cost control mechanism of PSS	E2, E3
MOL	Use and maintenance	Reverse channels and reverse logistic	E2
		Identify patterns of customers' use and profitability of PSS to propose new offers	E5
		Monitoring of opportunities of generation of new services based on historic, use patterns, and accumulate knowledge (within and outside company) of PSS	E3,E5
EOL	End of life support	Explore with the customers the image of company on sustainability and social aspects	E1
		New secondary markets and users	E2, E5
	Monitoring and	Developing new services extending the PSS life	E3

	feedback analysis	Identify patterns of customers' use to propose new services	E5

Particularly in this stage the frequency and consistence criteria was applied to perform the content analyses and inclusion of each activity in the improved version (M2) of method. The findings of this step of coding are then presented (Table 20). Another application of these results may be to insert these new activities of Sustainable VU in the final tables resulting of the coding 5_New detailed aspects realized in the previous step of coding.

During the content analyse o this stage, was performed comparing the new sources of sustainable of VU appointed by the specialists with the objectives of each task within each one of 15 phases of M1 method. Therefore, when the objective of new source suggested already was cover by an existent task, it was not considered. On the contrary, when the new source was not cover by an existent task or by a task resulting in the Focus group 1 it was considered to include in the version M2.

The following category of the coding process was 7_Tools Engineering or Management tools. The analyses in this step occurred by two step. First, the results of qualitative content analysis answers were obtained. And after this, these results was analysed against the literature results from chapter 4. The goal of this comparation was verify the best suited tools supporting the expected results in each activity of improved version of method (M3).

Table 21: 7_Tools Engineering or Management tools

Life Cycle	Phase of SPSS in M1	Suggested tools	Source
BOL	Requirements generation	Statistic tools	E2
		Brainstorming Empathy Mapping Design Thinking	E3, E5
		Technological roadmapping	E4, E5
		Persona Customer Value Chain Analsis (CVCA) Blueprint Survey market Segmentation and clusterization	E5
	Requirements identification	Business Model Canvas and Value Proposition Canvas	E2, E4
		Mapping of life cycle of product	E3
		Persona	E4
	PSS idea development	Work flow analysis (BPMN)	E2
	Concept generation	Design Thinking	E2, E5
		Simulation	E5
	Concept evaluation	Simulation and test with customers	E4, E5
	Concept development and evaluation	Value Mapping	E2

		Mapping new technologies of market	E3
		Simulation and prototipation	E5
	Detailed design	Systems to PSS modelling	E2
	Test (prototyping or simulating)	Satisfaction survey	E1
		Success factors	E2
	Final design	Indicators Management	E2
	Implementation and measure	Satisfaction survey with front office employers	E1
MOL	Use and maintenance	Green Supply Chain Management	E2
		Statistical tools and Data mining	E5
	Monitoring and evaluation	IoT	E4
EOL		Economic analysis Real options analysis	E5
	14. End of life support	Market survey with user regarding to image social and environmental of company	eu
		Mapping of the reverse chain	E2
	15.Monitoring and feedback analysis	FMEA and Statistic Control of Quality Requirements analysis	E2
		Business analytics	E4, E5

As results of this coding step, a list of several suggested tools to support the activities of design proposals was obtained. Some outcomes of this step have resonance with the findings from literature (Chapter 4). For example, as suggesting by the specialists, the Business Model Canvas (BMC) was applied to establish value proposition to PSS (Xing and Ness, 2016). As well as, several tools from Design thinking methodology was previously used in SPSS (Orloff and Heinz, 2015). During this process the possibility of apply in the EOL market surveys with the PSS' users regarding to image social and environmental of company, also emerged from insights of moderator.

Table 22: Results to the coding 8_Critical sources and tools

Life Cycle	Outcomes	Source
BOL	Clearly identify customer' demands	E1, E3, E5
	In the requirements identification step, after identifying the necessary customers' requirements, identify extra/additional benefits (social and environmental) that may be included in the offer. Precise definition of PSS costs and price before deployment.	E3
	In the requirements identification step, it is critical to obtain a clear and precise understanding of the current legislation and future changes in the current legislation rules.	E1, E5
	Explore suppliers' expertise and competences by establishing partnerships.	E1
	Explore expertise and competence available in the SME processes and employees.	E4, E5
MOL	In the Monitoring stage, it is important for the SME to use responsive real data obtained from the PSS user experience (e.g. Service data, CRM) to generate and offer additional value propositions (extending loyalty) to users in the PSS offer.	E1, E3, E4, E5
EOL	Developing new services extending the PSS life based on the historic, use patterns, and accumulates knowledge (within and outside company) of PSS.	E1, E3
	Extend the life cycle of custumer in the PSS.	E1, E4

The specialist E3 still emphasizes the importance of exploiting the full potential of the offering by stating:

> "It is important to overcome the expectation of the SPSS value proposition by adding additional solutions to the customers. For example, if economic gains are the most important dimension to the customer, the SME could show as added value social and environmental benefits that the PSS offer may provide."

Already regarding to the EOL, the E1 specialist highlighted that:

> "Although the product life cycle has ended and is exhausted, in this exhaustion there is an opportunity to articulate a new sale or service for the same customer, extending the life cycle and the customer experience in this PSS. That is, to use this step as a lever and articulation of a new business."

8.4 Enhancing the Eco-innovation-oriented Method to Support SPSS Proposals in Manufacturing SMEs

Aiming to improved and develop an enhanced version M2 of method, the results of Focus Group 1 and 2 was considered. The criteria to prioritize the inclusion of results were: the frequency of citation by specialists, the consistency and justification of exert and the concordance of these results with the finding from literature review (Chapter 3, 4 and 5). In this sense, the main findings obtained in each coding category/subcategory from Focus Group 1 (Table 3) and the respective implications and insights considered to the proposition of version M2 were the following:

Table 23: Implications of Focus Group 1 to the Method (M2)

Coding	Main implications to the method (M2)
1_PSS	Develop integrated solutions.
2_PSS	Two pathways for value proposition: pull market (driven by customer demand) and add value by adding services. PSS is associated with dematerialization.
3_PSS models	Increase the degree of formalization of SME to offer a new business model such as the PSS. Explore flexibility allowing positioning along the chain.
4_PSS models	Explore the SME's flexibility and mobility to contact customers. Explore partnerships. Analysis of the value chain. SME needs simple and fast design method.
5_Reference models	There is a need of a reference method to PSS model design for SMEs.
6_Necessary phases	Simplify and reduce the number of phases. Identify and validate business opportunities at the beginning and end of the method. Insert a zero step of identifying business opportunities. Assess the impact on the three dimensions of sustainability. Stage to seek partners to design the network necessary to elaborate the value proposition. Mentoring and external support giving an external look (e.g. consulting, government support,

	universities). Mapping of SME competences. Explore MOL aiming propose new value offers and sustainable VU.
7_ Necessary tasks	Explore product life cycle analysis at the beginning and end of the life cycle (3Rs, cradle-to-cradle). Task to the definition of PSS leader.
8_ Necessary tools	Use of templates of application of the tools and present options of tools to realize the tasks. Design Think tools, Business Model Canvas and Canvas Value Proposition to identify and define opportunities. Customer Journey Map to identify requirements. Multicriterial analysis to select the services that will be included in the value proposition. Simulation of services
9_Interactions	Explore MOL aiming propose new value offers or enhance the current proposal. Mentoring and external support giving an external look (e.g. consulting, government support, universities).
10_Architecture and 11_Critical aspects	Method suitable for product-oriented PSS and established companies. Simplified architecture. Use simpler terms to name of steps along the proposed method. Need be agile allowing rapid prototyping. Shows the benefits and financial return to the customer.

In the same manner, the main findings obtained in each coding category/subcategory from Focus Group 2 (Table 12) and the respective implications and insights considered to the proposition of version M2 were the following:

Table 24: Implications of Focus Group 2 to the Method (M2)

Coding	Main implications to the method (M2) to enhance Sustainable VU
1_Factors	Understand customers' pains. Establish partnerships.
2_Actions and tools	Understand the position within the supply chain. Understand the competitive dimensions required by the market. SME's borders of action in its value chain and market. Value Proposition Canvas to identify the pains. Customer Value Chain Analysis (CVCA). Benchmarking and technology mapping.
3_Stages	Explore BOL and mainly MOL and EOL with sustainable VU framework.
4_New sources 5_ New aspects	Use the sources and aspects of Sustainable VU as a verification list during the proposal design.
6_New activities	BOL: Verify the end of life of technologies used by the company and explore new technologies Verify legal demands. Partnerships. Identify potentials new segments, customers and suppliers. Mapping extra benefits in social and environmental aspects. Evaluation of portion of Product and Service suited to the level of risk accept by SME ICT systems to PSS offer. Identify opportunities and Factors Critical Success of PSS. Cost system and cost control mechanism of PSS. MOL: Reverse channels. Identify patterns of customers' use and profitability of PSS to propose new offers. EOL: Explore with the customers the image of company on sustainability and social aspects. Developing new services extending the PSS life.

7_Tools	BOL: Design Think and Business Model Canvas Customer Value Chain Analysis Survey market Blueprint Success factors Simulation MOL: Monitoring social networks EOL: Reverse channels. Economic analysis. Business analytics.
8_Critical sources and tools	All outcomes.

Considering this summary of results (Table 22, 23) and the findings achieved in mainly in Chapter 5, the enhanced version (M2) of reference method eco-innovation-oriented to support the SPSS design proposals for manufacturing SMEs was obtained. Based on these results, the general logical adopted to the organization of the method in order to respond the gaps from literature and the previous result is expressed (Figure 3).

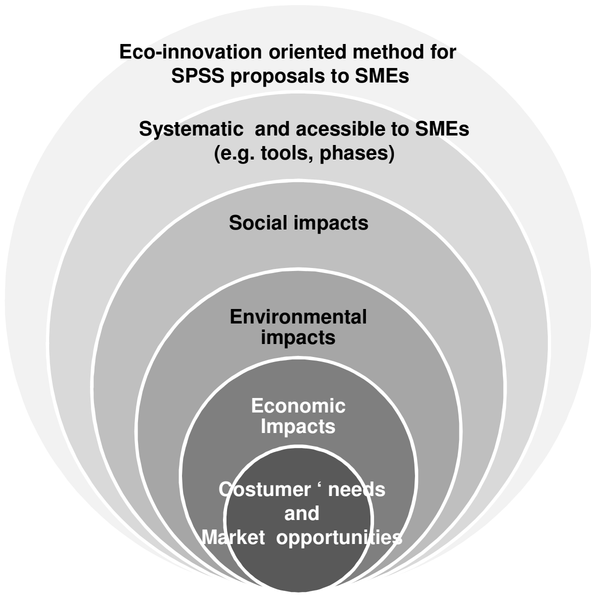

Fig. 3. Organization of the method

The Figure 3 represents the logic pathway adopted to made the proposition of the method considering the improvement noted by specialists of the Focus Group 1 and 2 integrating with the research gaps from literature, obtained in the chapters 2, 4 and 5.

First, a simplified and visual method (M2) facilitating the understanding by the SMEs was obtained. (Fig. 4). Second, a complete version including the internal architecture presented in a step-by-step format including the suggested tools was proposed (Fig. 5). In this version M2 several changes and improvement turning the method most suited to manufacturing SMEs context were realized when comparing with the previous version M1.

Considering the previous summary of results, the proposed method is suitable and oriented to the following assumptions:

- The intention of method is be oriented to all the kinds of manufacturing SMEs which aim added value to the business from goods.
- The method should be used as a reference method serving as a guide. Therefore, its objective is allow adaptations by the SME or external consultant along the proposal design.
- The SME may use the method bases in a pull market logic, that is, driven by customer demands and or else when that SME want add value to the business by adding services.
- The method is oriented for product-oriented SMEs enabling SPSS offers.
- The method also is oriented for already existent or established enterprises.

The Fig. 4 represents the version M2 of method proposed a simplified visual representation of method. The objective of this is creative representation is facilitate the understanding of SMEs using a visual language.

Fig. 4. Version M2 of method proposed

The main points that made part of organization of this version M2 are explained:

The method is organized in four main layers. The central layer is the customer and the value proposition. This is the bottom line to next steps of method. The next three layers represented the sustainability dimensions. The economic dimension is in yellow colour, the environmental dimension in green colour and social dimension in blue colour. The inclusion of these four layers mean that the focus on the value proposition and in the three dimensions of sustainability must be considered across all phases and during the execution of all activities of method. The inclusion of a life cycle perspective necessary due the gaps from literature (Chapter 3 and 4) stating the lack of a life cycle perspective of PSS artifacts available.

A stage zero related to comprehension of current situation of SME was added. In this stage three main activities are made: (i) the strategic analysis of SME positioning in the market; (ii) the identification of the stakeholders and actors involved influencing the SME business; (iii) the identification of market opportunities.

To the BOL stage of life cycle, seven main sub-phases are proposed. This emphases is to suitable to sustain the product-oriented SMEs assumption. These sub-phases adopted nomenclature similar to Design Thinking approach. The first sub-phase is the beginning of the ideation process of SPSS proposal named “Ideation: Identifying opportunities and the Value Propositions”. In this sub-phase three main activities are suggested: (i) identification of the key customers and key customers’ needs; (iii) identify and define the value proposition to the key customers; (iii) do the statement of ideal final result of value proposition based on key customers and marketing opportunities.

The second sub-phase of the ideation process is named “Ideation: Searching systematic and radical innovations to value proposition”. This sub-phase is composed by three main activities: (i) realize the benchmarking analysis in the market of similar value propositions suggested in the previous sub-phase; (ii) improving the value proposition considering the evolutionary trends and factor involved in this value proposition; (iii) refine the value proposition by adding in a systematic way incremental or radical innovations.

The third sub-phase of the ideation process is “Enhance the value proposition”. In this phase the main activity developed is the enhance of the development of the value proposition in an economic, social and environmental perspective of analysis. A more systemic look to the value proposition is the given in this phase.

The following sub-phase is the “Concept definition” composed by five main activities: (i) the first occur the generation of SPSS modular concepts evolving the value proposition resulting in previous sub-phase. In this activity, is very important to consider the existents service already offers by SME. The goal here is create different service packages to specific customer segment and their needs and also analyse the possibility of use this combination to others segments; (ii) second, is realized the evaluation sustainable of alternatives and scenarios for the SPSS modular concepts; (iii) third, is made the definition and choice of SPSS concept that will be adopted by SME; (iv) fourth, is defined the suitable performance measure system and KPIs (economic, environmental, social based) to measure the concept defined; (v) fifth, is indicated to SME organize fast tests or social-technical experiments of SPSS concept evolving key customers or even Fablabs etc.

The “Resource analysis” sub-phase is composed by three activities: (i) verify the competences, financial resources, internal resources, process and constraints to implementation of SPSS offer previously defined; (ii) identify and define strategic companies partners/network to develop the SPSS offer, and; (iii) if necessary, define the mentoring/external advisor (e.g. consulting, university, governmental programs) to develop and support the SPSS offer.

In the “Concept development” two main activities are realized: (i) Develop the preliminary concept design and (ii) develop detailed concept design (e.g. simulation, modelling structure, layers, interfaces, subsystems and integration of subsystems). Depending of complexity of value proposition, this phase may be performed in single activity.

The “Test” phase has two main activities: (i) first is suggest made a real, detailed and effective test of SPSS offer analysing the empathy and behaviour of users and also evaluating if ideal final result of value proposition is met; (ii) next, based on results of test it is necessary implement improvements.

To the MOL stage of life cycle, one main sub-phase is proposed “Implementation”. That is, the realization of SPSS offer in the market. In this phase, three activities are indicated: (i) monitoring and evaluate of the SPSS’ performance over time (e.g. using measure system, KPIs, users’ behaviour); (ii) Implement continuous improvement actions in the SPSS offer based on its performance; (iii) based on the analyses of SPSS’ performance over time and in the continuous improvement actions, identify and propose opportunities to develop new SPSS offers. These new opportunities can have two possible strategies: add value propositions or features to the existent offer or still, develop a different SPSS offer.

To EOL stage of life cycle oh method has three main sub-phases. The first is the “End of Life support” in which occur the practical implementation of actions to disposal, such as the 4Rs (reuse, remanufacturing, recycle, recovery), cradle-to-cradle, etc. The second phase “Monitoring and feedback analysis” occur the analysis and definition of continuous improvement actions to the SPSS offer. Similar to MOL, there are here two possible strategies: add value propositions or features to the existent SPSS offer or still, develop a different SPSS offer and new markets. It is important state that the main criteria to select these actions must be extend the SPSS life cycle. Finally, the last and relevant activity of method is the mapping of lessons learned in an internal perspective of the SME and also in an external perspective focusing in the SPSS performance in the market. The goal of this step is generate several opportunities to restart the life cycle scaling up SPSS business models in the same or different customer segments. The internal structure of method M2 and the main interactions between the phases and activities also is detailed (Fig. 3).

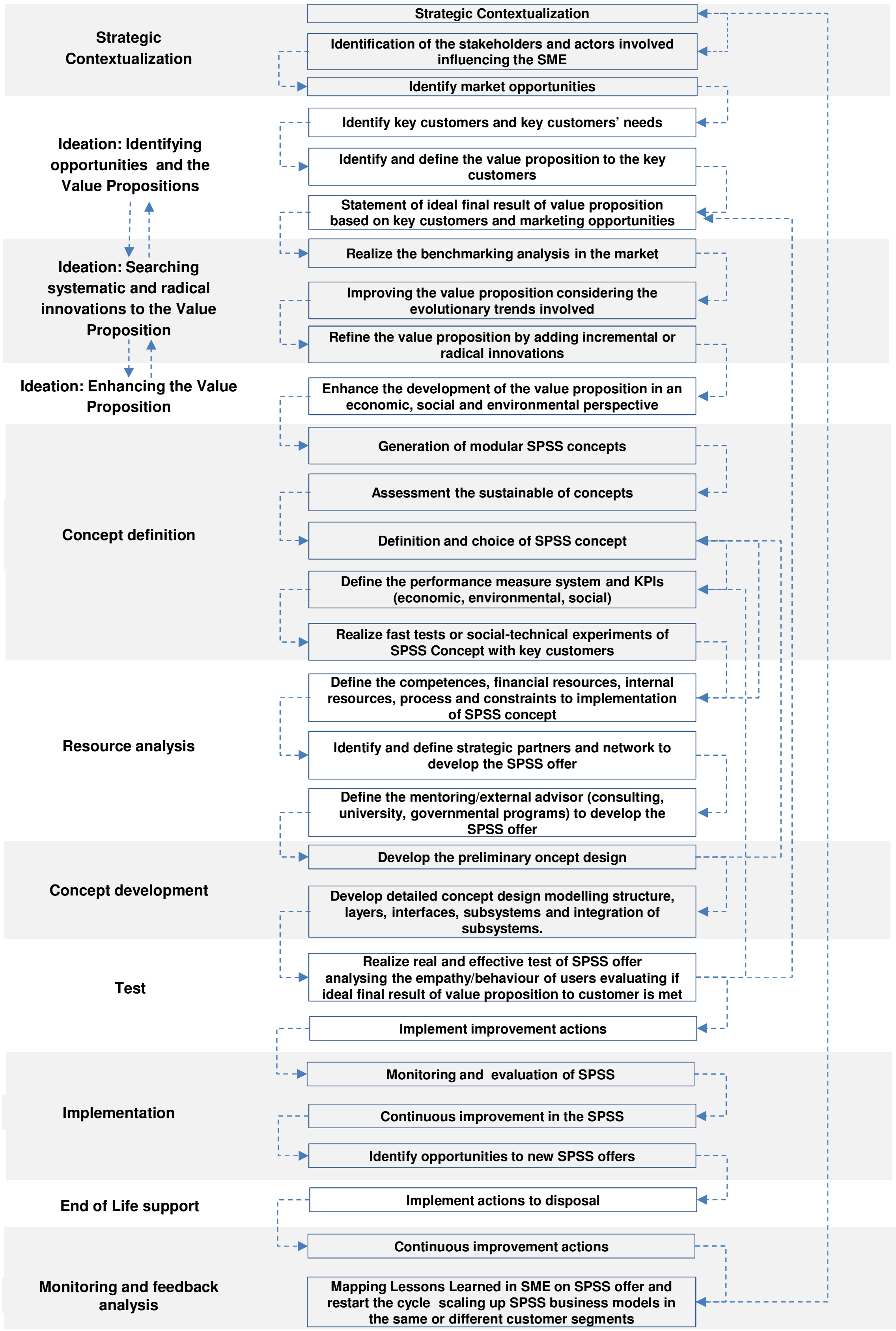

Fig. 5. Internal structure and interactions of method M2.

This Figure 5 represents the main relations of feedback, the most important cause-effect relations and interactions. Finally, the elements of version M2 of method containing the suggested tools to the realization of each activity along the life cycle and the focus of each sub-phase, if in Service (S), Product (P) or PSS also is suggested to a better comprehension of architecture of method (Table 25).

Table 25 – Elements of version M2 of the method

PSS Life cycle	Phase of PSS	Activities	Suggested tools	Focus in Service (S), Product (P) or PSS
Understanding the current situation	1.Strategic Contextualization	1.1 Strategic analysis of SME positioning in the market. 1.2 Identification of the stakeholders and actors involved influencing the SME 1.3 Identify market opportunities	1.1 SWOT + PESTEL 1.2 Mapping stakeholders- DT 1.3 Value Mapping Tool	P+S
BOL	2.Ideation: Identifying opportunities and the Value Propositions	2.1. Identify the key customers and key customers' needs 2.2. Identify and define Value Propositions to the key customers 2.3 Statement of Ideal Final Result of Value Proposition(s) based on key customers and marketing opportunities	2.1 Environmental QFD (QFDE) 2.1 Persona + 2.1 - 2.2 Canvas Value Proposition + Contradiction Matrix 2.3 Ideal Final Result	P+S
	3.Ideation: Searching systematic and radical innovations to Value Proposition (s)	3.1 Realize the Benchmarking analysis in the market 3.2. Improving the Value Proposition considering the evolutionary trends involved 3.3 Refine the value proposition by adding incremental or radical innovations	3.1. Benchmarking in the market + PSS Benchmarking 3.2. Trend Matrix (DT), 9 Windows Matrix 3.3. 40 IPs to P, S, PSS + 76 Standard Solutions	P, S, and PSS
	4. Ideation: Perfecting the Value Proposition(s)	4.1 Develop and improve the Value Proposition in an economic, social and environmental perspective	4.1 Sustainable Business Model Canvas	P+S
	5. Concept definition	5.1 Generation of modular SPSS concepts. 5.2 Evaluation sustainable of alternatives/scenarios. 5.3 Definition/choice of SPSS concept 5.4 Define the performance measure system and KPIs (economic, environmental, social based) 5.5 Realize fast tests or social-technical experiments of SPSS Concept with key customers, Fablabs i.e.	5.2 - 5.3 Assessment of current sustainability (economic, environmental, social) versus sustainability of Value Proposition + Added value current (economic, environmental, social) versus Added value of Value Proposition + Assessment of criteria to Great Value Propositions + Ideal Final Result 5.4 KPIs matrix 5.5 Fast test, interview	PSS
	6. Resource analysis	6.1. Verify the competences, financial resources, internal	6.1 - 6.2 - 6.3 To develop a map of	PSS

		resources/process and constraints to implementation of SPSS offer. 6.2 Identify and define strategic companies partners/network to develop the SPSS offer, and; 6.3 Define the mentoring/external advisor (consulting, university, governmental programs) to develop the SPSS offer	the offer of resources versus opportunities.	
	7. Concept development	7.1. Develop the Preliminary Concept design 7.2. Develop detailed concept design (simulation, modelling structure, layers, interfaces, subsystems and integration of subsystems).	7.1 - 7.2 Blueprint , Journey Map, Lego play	PSS
	8. Test	8.1 Realize real and effective test of SPSS offer analysing the empathy/behaviour of users evaluating if Ideal Final Result Value Proposition to customer is met 8.2 Implement improvement actions.	Real customers and employees Socio technical experimentation	PSS
MOL	9. Implementation	9.1 Monitoring and evaluation of SPSS (KPIs, user behaviour) 9.2 Continuous improvement in the SPSS offer 9.3 Identify opportunities to new SPSS offers		P or S
EOL	10. End of Life support	10.1. Implement actions to disposal 4Rs (reuse, remanufacturing, recycle, recovery) etc		P or S
	11.Monitoring and feedback analysis	11.1 Continuous improvement actions		PSS
	12. Mapping Lessons Learned in SME on SPSS offer and restart the cycle scaling up SPSS business models in the same or different customer segments.			P, S, and PSS

In order to enhance and validate this version M2, a third Focus Group was realized. After include improvements in M2, the main outcome of Focus Group 3 was version M3 of reference method.

8.4.1 Focus Group 3

8.4.1.1 Objectives and target participants

Following the same criteria of previous Focus Groups 1 and 2, this Focus Group 3 also adopted the Reichertz' protocol and the proposed steps to develop the qualitative content analysis of results. In order to achieve the objective of this thesis resulting in an effective contribution to the literature on PSS field, the objectives of this Focus Group 3 were:

- To validate and insert or modify in M2 new elements of value addition to customers in a sustainable perspective (environmental, social and economic).
- To validate and insert or modify the general architecture among the actors of the method and proposed new connections/interactions.
- To validate and improve method M2 current proposing or modifying phases, tasks, tools and interactions.

To achieve these previous objectives the profile of participants is presented (Table 26).

Table 26 - **Participants of Focus Group 3**

Specialist	Academic Background	Position	Research Focus	PSS Background
E1	Post-doc in in Industrial Engineering. PhD in Meachanical Engineering. M.Sc. in Mechanical Engineering.	Head of Department. Full Professor.	PSS development and PSS transition	Experience in research and teaching in PSS by 9 years. Several scientific publications in SPSS and R&D. Professional experience in manufacturing SMEs.
E2	M.Sc. in Industrial Engineering in PSS field.	Researcher in PSS.	PSS development and PSS transition	Experience in research on PSS by 6 years. Professional experience as Head of R&D and services in large companies by 35 years.
E3	PhD student in Industrial Engineering Engineering in PSS field.. M.Sc. in Industrial Engineering.	Researcher. Associate Professor.	PSS development and PSS transition	Experience in research and teaching in PSS by 3 years. Professional experience in manufacturing large companies.
E4	M.Sc. in Industrial Engineering Engineering in PSS field.. Thesis developed in Design Thinking in PSS.	Researcher in PSS.	PSS development	Experience in research and consulting in PSS by 2 years. Professional experience 4 years manufacturing large companies.
E5	M.Sc. in Industrial Engineering Engineering	Researcher. Associate	PSS transition	Experience in research and teaching in PSS by 1 year.

	in PSS field.	Professor.		Professional experience 6 years in manufacturing large companies.
E6	PhD student in Industrial Engineering Engineering in PSS field. M.Sc. in Statistic.	Researcher.	PSS development	Experience in research in PSS by 3 years. Professional experience by 3 years in manufacturing SME.

8.4.1.2 Coding and Research Outcomes

The post-field work activities of Focus Group included the data preparation, analysis, coding (Table 27) and the interpretation of the inputs. The findings to each round of questions are then discussed as follow.

Table 27: Coding and categories

Coding	Categories	Subcategories	Source in Focus group
1_PSS design	Steps to generate Sustainable Value	Steps of PSS design with greater potential to generate Sustainable Value (economic, environmental and social)?	Opening questions
2_Critical factors	Critical factors to PSS offer and sustainability	Critical factors to PSS offer and critical factors related to sustainability in SMEs	Introductory questions
3_Barriers	Barriers to transition and to obtain sustainability	Barriers to SME make a successful transition and barriers to incorporate sustainability in the offer	
4_Ideaity	Ideal attributes of method	Which ideal attributes should have a focused method for realizing proposal of SPSS in SMEs?	Transition questions
5_Nomenclatu re	Nomenclature to phases and activities	Adopt a generic or a specific product x service nomenclature to the name of phases and activities?	Key questions
6_Life Cycle	Consistence to SMEs context	Are the processes, interactions and tools suited to SPSS design in SMEs context?	
7_Macro perspective	Consistence to SMEs context	General evaluation of method.	
8_Interactions	Main interactions	Main interactions between actors x phases to increase the value proposition to customer?	
9_ Inputs and outputs	Main inputs and outputs between the actors and phases	What are the main inputs and outputs between the actors and phases to increase the value proposition?	
10_Modular	Generation of modular SPSS concepts	Which processes in the method are more suited to generation of modular SPSS concepts?	
11_Resources	Strategies to verify the resources	What is the best way to verify the competences, financial resources, internal resources/process and constraints to implementation of SPSS offer?	
12_Extend the life cycle	Extend the life cycle of SPSS	Extend the life cycle of SPSS	Ending questions

Reichertz (2014) stated that this frequency is a relevant indicative of validity of results. Hence, this was main criteria adopted to include and present the findings to all questions during the coding across the subcategories. The final results of qualitative content analysis was summarized (Table 28).

Table 28: Main outcomes

Code	Main Outcomes	Source
1_PSS design	Identify customer' needs, stakeholders and after define requirements following a continuum interaction.	E1, E5
	Include sustainability in very beginning of ideation process.	E2, E4, E6
	Concept generation and in opportunities identifications.	E4
2_Critical factors	Concept validation and test with customers before implementation.	E4
	The cost and pricing of PSS	E5
	Environmental legislation	E6
	Realized if the customers and stakeholders will pay by the value the SME will offer	E1, E2
	Search inspiration in service development field	E1
3_Barriers	Change the mind-set of SME and the market	E1, E2
	Financial aspects	E2, E4
4_Ideality	Must be flexible and simplified Support an agile development User centred	E1
	Must be flexible and agile	E2
	Have a internal leader	E4
	Have external support to think "out of box"	E2
	Have clear and well define steps	E5
	Fast application of proposal Customer evolvement	E3
	Have a market driver pulling the sustainability or social	E2, E4
	Society and community oriented	E1
5_Nomencla-ture	In use-oriented PSS it is necessary chance the semantic. In product-oriented the nomenclature may be more service oriented.	E2
	The product oriented PSS should have a integrated terminology	E3, E4
	The method must be a reference method supporting the SME or an external mentor. In this case, to product-oriented PSS the nomenclature may be generalized.	E1

Regarding to steps of PSS design with greater potential to generate Sustainable Value the outcomes indicated made this analysis in the beginning of method. This reinforces previous findings from literature (Barquet et al., 2016). The critical factors to PSS offer and critical factors related to sustainability in SMEs are related with the cost and acceptation of customer. Similar to results of previous focus group, also was contacted this which the method should be flexible, agile and simplified. Also was suggested that the terminology of method should be generalized without specification to service and product activities.

The results of the remaining coding (6_Life Cycle, 7_Macro perspective, 8_Interactions, 9_ Inputs and outputs, 10_Modular, 11_Resources, 12_Extend the life cycle) were summarized as follow:

Table 29: Main outcomes

Understanding the current situation Strategic Contextualization • The activity 1.3 was modified to Identify market opportunities and sustainable-oriented opportunities. • The interaction with the phases 2 and 5 was added as relevant. • The tool VOC added to activity 1.3.
Beginning Of Life 2. Ideation: Identifying opportunities and the Value Propositions: • Was added the activity 'Realize the Benchmarking analysis in the market' that was in M2 in phase 3. • The interaction with the phases 1, 3, 4, and 5 was added as relevant and the interaction with 9 was inconsiderate. • In the activity 2.3was added the need of analyse the 'internal ideas of enterprise'. • Regarding the tool, Journey Map, Empathy Map, Focus Group with customers and Interview with customers was added to activity 2.1 and Persona was excluded. 3.Ideation: Searching systematic and radical innovations to Value Proposition (s): • The interaction with the phase 5 was added as relevant. 4. Ideation: Perfecting the Value Proposition(s): • The interaction with the phase 5 was added as relevant. • The focus of analyse is the PSS. 5. Concept definition • Considering that not all concept will be suited to modular design, the activity 5.1 was changed to 'Evaluate the need of modular SPSS concepts to sustain or differentiate the Value Proposition.' • The interaction with the phases 1, 2, 3, 4, and mainly 7 and 8 was added as relevant. • The activity '5.2 Propose scenarios to the concept' was added. • The tool Journey Map future was added to support the activities 5.3 and 5.4. • The activities of phase '8. Test' of M2, was added as final activities of this phase. 6. Resource analysis • This phase was renamed to 'Resource definition'. • In the activity 6.1 was added the need of define improvement actions, as for example, improve the gaps of competence to implement the offer (e.g. training to employers). • The interaction with the phases 7, 8 and 9 was added as relevant. • Blueprint tool was added to activity 6.1. 7. Concept development • This phase was renamed to 'Detail design'. • The interaction with the phases 5, 6, 8 and 9 was added as relevant. • The activity 7.1 was excluded. 8. Test • This phase was renamed to 'Launch'. • The activities of this phase were moved to end of phase 5. Concept definition. • Two activities were added: 8.1 Validate the detailed concept design of SPSS in real context before go forward and 8.2 Validate how the value chain of SPSS is running.
Midle of life 9. Implementation

• This phase was renamed to 'Use'. • In the activity 9.1 was added the need of monitoring the SPSS behaviour.
End of life 12. Mapping Lessons Learned • Was indicated to collect lessons learns along all phases of design of SPSS proposal design. In this case, the Contradiction Matrix oriented to product and service also was inserted to leverage the potential of solving problems and generate lessons learned.

The overall conclusion is that was found a significant level of concordance when comparing some results of Focus Group 3 and 2. In this sense, the convergence regarding the tools and the most part of phases and activities suggested to each phase reinforces this aspect. On the whole, as result of this Focus Group, some activities were re-sorted and the name of some phases was changed. Besides, several interactions between the phases were suggested. Thus, considering the inclusion of all previous results of this focus group, an enhanced version M3 of method was proposed. The Figure 6 represents the version M3 of method in a simplified visual representation.

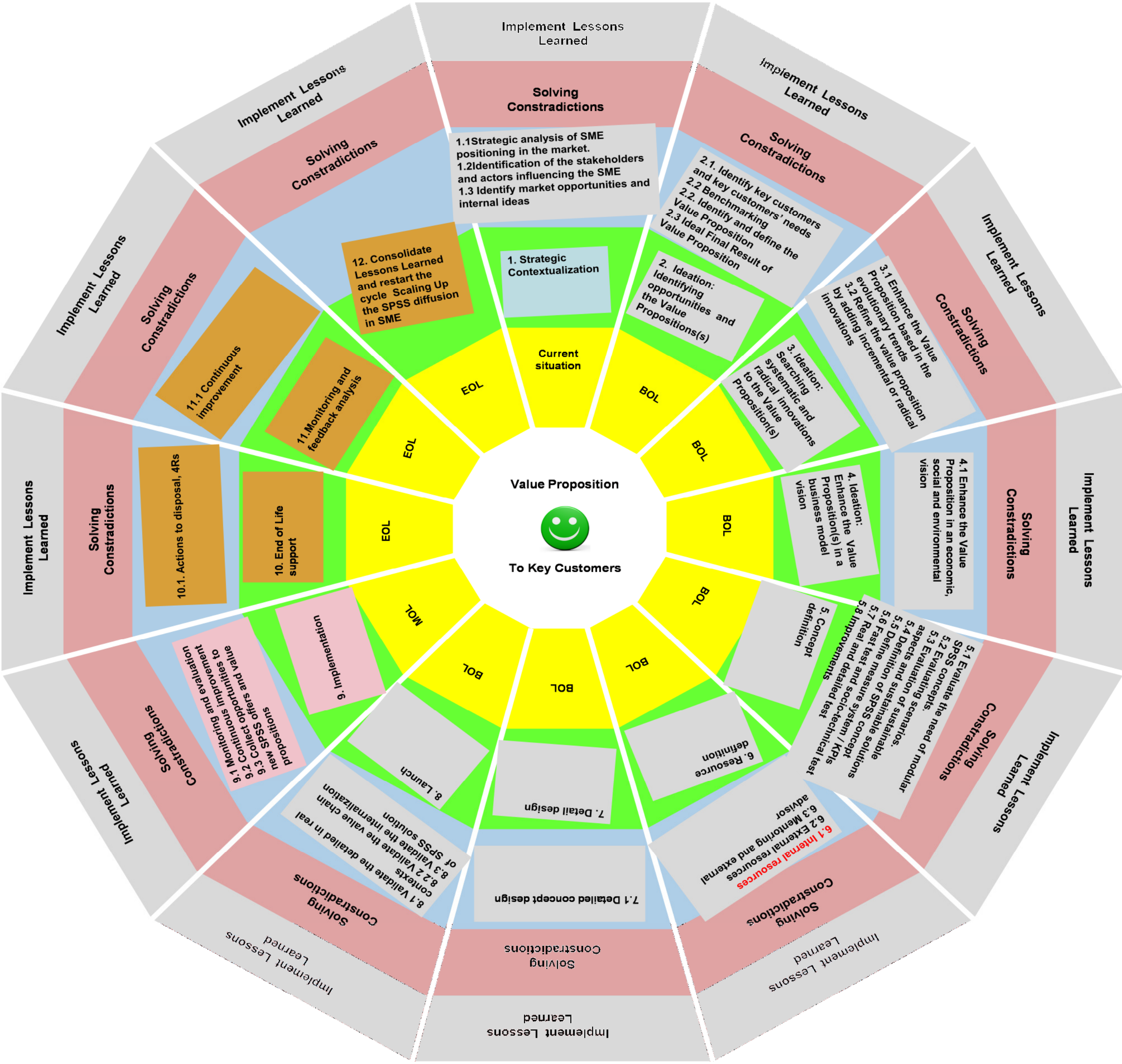

Fig. 6. Version M3 of method proposed

The internal structure of method M3 and the main uptdated interactions between the phases and activities also are detailed (Fig. 7). However, a system perspective was given to internal interaction between the elements of the method, in which the activities of each realationed phase are considered.

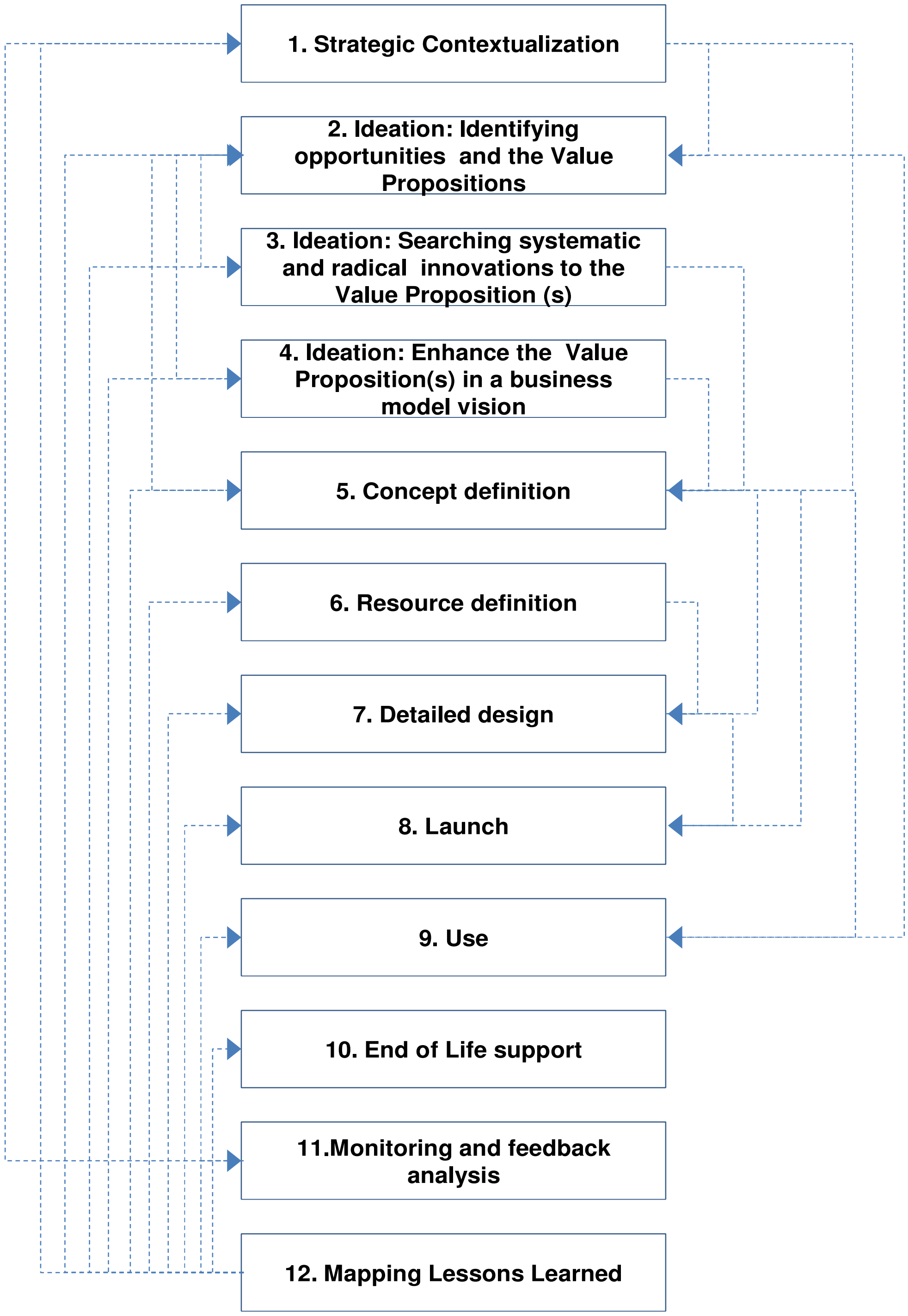

Fig. 7. Internal structure and interactions of method M3.

Finally, the entire list of elements of version M3 of method containing the suggested tools to the realization of each activity along the life cycle and the focus of each sub-phase - if in Service (S), Product (P) or PSS - also is suggested to a better comprehension of architecture of method (Table 30).

Table 30 – Elements of version M3 of the method

PSS Life cycle	Phase of PSS Design	Process	Feedback, strong cause-effect or i(n)teractions	Suggested Tools Related	Outputs	Focus in Service, Product or PSS
Understanding the current situation	1.Strategic Contextualization	1.1 Strategic analysis of SME positioning in the market. 1.2 Identification of the stakeholders and actors involved influencing the SME 1.3 Identify market opportunities and sustainability-oriented opportunities	2, 5	1.1SWOT + PESTEL 1.2Mapping stakeholders - DT 1.3 VOC, Value Mapping Tool	1.1-1.2 Comprehend the SME positioning in the market. 1.3 Based in the positioning in the market and in the custumer' voice identify possible ideas for sustainable innovations.	P+S
BOL	2. Ideation: Identifying opportunities and the Value Proposition	2.1. Identify the key customers and key customers' needs 2.2 Realize the Benchmarking analysis in the market 2.3. Identify and define Value Proposition to the key customers 2.4 Statement of Ideal Final Result (IFR) of Value Proposition based on key customers, marketing opportunities and internal ideas of enterprise. 2.5 Realize test and validation of the Value Proposition with the key customers, Fablabs, etc.	1, 3, 4, 5	2.1 Current Journey Map, Empathy Map, Focus Group with customers, Environmental QFD, Interview with customers 2.2 Benchmarking in the market and PSS Benchmarking 2.3 Canvas Value Proposition, Contradiction Matrix 2.4 Ideal Final Result 2.5 Tests, prototypation, social-technical experiments, etc	2.1 Identify what are the key customers and the key customers' needs. 2.2 An analysys of cases of excellence similar wich already attending the custumer' needs. 2.3 A clear defintion of Value Proposition to key customers. 2.4 A formalized statement of IFR of the Value Proposition. 2.5 An initial validation of Value Proposition with the key customers is performed and continuous improvement is applied.	P+S
	3. Ideation: Searching systematic and radical eco-innovations to the Value Proposition	3.1 Enhance the Value Proposition considering the evolutionary trends involved 3.2 Refine the Value Proposition by adding incremental or radical innovations 3.3 Realize test and validation of the Value Proposition with the key customers, Fablabs, etc.	2 in looping, 5	3.1. Trend Matrix (DT), 9 Windows, Laws of Trend Evolution 3.2. Contradiction Matrix to P, S, PSS and 76 Standard Solutions. 3.3 Tests, prototypation, social-technical experiments, etc	3.1 Add improvements in the Value Proposition to reach the IFR applying evolutionary thinking 3.2 Add improvements refining the Value Proposition applying out-of-box thinking. 3.3 Validation of Value Proposition with the key customers is performed and continuous improvement actions are applied.	P, S, and PSS
	4. Ideation: Enhance the Value Proposition in	4.1 Develop the Business Model vision to attend the Value Proposition in an economic, social and environmental perspective.	2, 3 in looping, 5	4.1 Business Model Canvas (social, environmental, economic)	4.1 A formalized and filled social, environmental and economic Business Model Canvas.	PSS

	a Business Model perspective	4.2 Enhance the Business Model based in the eco-innovation guidelines along the lyfe cicle		4.2 Eco-innovation guidelines oriented to the lyfe cicle of Business Model	4.2 A list of several incremental and radical eco-innovations to include along the life cycle of SPSS Business Model.	
	5. Concept definition	5.1 Evaluate the need of modular SPSS concepts to sustain or differentiate the Value Proposition. 5.2 Propose scenarios to the concept of Business Model 5.3 Evaluation of sustainability potential of SPSS concept 5.4 Definition and choice of SPSS concept 5.5Define the performance measure system and KPIs (economic, environmental, social based) 5.6 Realize real and detailed test of SPSS concept evaluating if the Ideal Final Result Value Proposition to customer is reached	1, 2, 3, 4, 7, 8, 9	5.3 - 5.4 Check list of sustainability assessment (economic, environmental, social) current x Value Proposition, Added value (economic, environmental, social) current x Value Proposition, Assessment to Great Value Propositions, IFR, Future Journey Map, SPSS concept form 5.5 KPIs matrix 5.6 Tests, prototypation, social-technical experiments, etc	5.1 A decision on the need or not of include modular concepts in the SPSS offer. If necessary, define the modularized packs. 5.2 If necessary, realize a comparative anaysys between different scenarios of Business Model previously obtained. 5.3 A detailed assessment of sustainability potential of SPSS concept in several criteria 5.4 Formalize the choice of Business Model 5.5 A list of main KPIs to sustain the Value Propostition is defined and will be user to monitoring the EOL of SPSS. 5.6 Validation of Value Proposition with the key customers is performed and continuous improvement actions are applied.	PSS
	6. Resources definition	6.1.Analyse the competences, financial resources, internal resources/process and constraints to implementation of SPSS offer and define improvement actions 6.2 Identify and define strategic partnerships and network to develop the SPSS offer. 6.3 Define the mentoring or external advisor (consulting, university, governmental programs) to develop the SPSS offer	5.4, 7, 8, 9	6.1 Blueprint, Contradiction Matrix 6.2 - 6.3 Data base of possible partners. To develop a map of the offer of resources and opportunities.	6.1 All kinds of necessary resources emerged during the Blueprint map of Value Proposition are detailed in a comprehensive matrix. An analysys of priorization of these resources is realized immediatally. Constradicitions found between the resources necessary versus resources available are solving by Contradiction Matrix. 6.2 The strategic alliances and partnerships to develop the SPSS offer are identified and defined within the supply chain and externally. 6.3 The mentoring to support the SPSS transition in the SME is defined.	PSS
	7. Detailed design	7.1. Develop detailed concept design of SPSS offer (simulation, modelling structure, layers, interfaces,	5.4, 5, 6, 8, 9	7.1 Blueprint, Lego play, CAD oriented to PSS modelling.	7.1 A detailed design of SPSS Busines Model is realized, simuled or tested in	PSS

		subsystems and integration of subsystems).			real context. This detailied design must contain the integration etwenn the network of actors, infraestructure, stakeholders, entities	
	8. Launch	8.1 Validate the detailed concept above in a real context of SPSS solution before go forward 8.2 Validate how the value chain of SPSS solution is running 8.3 Validate the internalization of SPSS solution within the SME		8.1-8.2-8.3 Tests, prototypation, simulation, social-technical experiments, etc	8.1-8.2-8.3 A final validation of all elements of SPSS offer is realized in a real context of SPSS offer applying tests, simulations, social-technical experiments etc.	PSS
MOL	9. Use	9.1 Monitoring and evaluation of SPSS (KPIs, user behaviour, SPSS behaviour) 9.2 Continuous improvement in the SPSS offer 9.3 Identify opportunities to new SPSS offers	2, 5.4	9.1 Painel of indicators 9.2-9.3 Action plan	9.1 Mainly in the first period of use of SPSS a daily and continuous process of monitoring and evaluation of KPIs previously defined, user behaviour and SPSS behaviour is performed. The interval of monitoring and evaluation will be adjusted along the SPSS use. 9.2-9.3 Actions of continuous improvement in the SPSS offer are applied during its use stage and new opportunities to develop possible new SPSS offers are identified and avaluated	PSS
EOL	10. End of Life support	10.1. Implement action plane previously defined to disposal (4Rs: reuse, remanufacturing, recycle, recovery; C2C, etc)	5, 6, 7	10.1 Action plan of disposal strategies	10.1 Are implemented the actions defined to the EOL of SPSS	P, S and PSS
	11.Monitoring and feedback analysis	11.1 Continuous improvement actions	1	11.1 Action plan	11.1 A set of continuous improvement actions to the SPSS offer are consolidated. New opportunities to develop possible new SPSS offers also are identified and avaluated	P, S and PSS
	12. Lessons learned	12.1 Mapping and consolidate Lessons Learned in SME on the SPSS offer and restart the cycle scaling up SPSS business models in the same or different customer segments	All (conforme as oportunidades mapeada, a interação pode existe com qualquer fase anterior dddependdde do rumo a seguir	12. Database of Lessons Learned	12.1 A comprehensive Database of Lessons Learned collected in all previous steps of SPSS design are consolidate and are bottom line to new SPSS offers.	P, S and PSS

Laslty a final step of validation of method was realized. In this stage, the version M3 of method was discussed with a set of seven experts in PSS. Some of expert's interviewed are considered world recognized experts in PSS field. None of them participated of previous steps of research. O objective of this stage was enhancing the current version of method. Hence, in-depth interview were organized in presencial sections when the acess to the expert was available, and also online sections when the expert was situated in another country.

Table 31: Session of in-depth interview

Session	Participants	Duration
1	Especialist 1 (E1) Especialist 2 (E2) Especialist 3 (E3)	2h:30min
2	Especialist 1 (E1) Especialist 2 (E2) Especialist 3 (E3) Especialist 4 (E4)	3:10min
3	Especialist 5 (E5)	1h:15min
4	Especialist 6 (E6)	1h:30min
5	Especialist 7 (E7)	1h:05min
6	Especialist 8 (E8)	30min

As results, new improvments were added in the method. The first was including a more emphasis in eco-innovation. In order to attend this, the use of eco-innovation guidelines along the design of SPSS offer was added in the scope of method (Fig. 8). Hence, a version M4 of method was proposed.

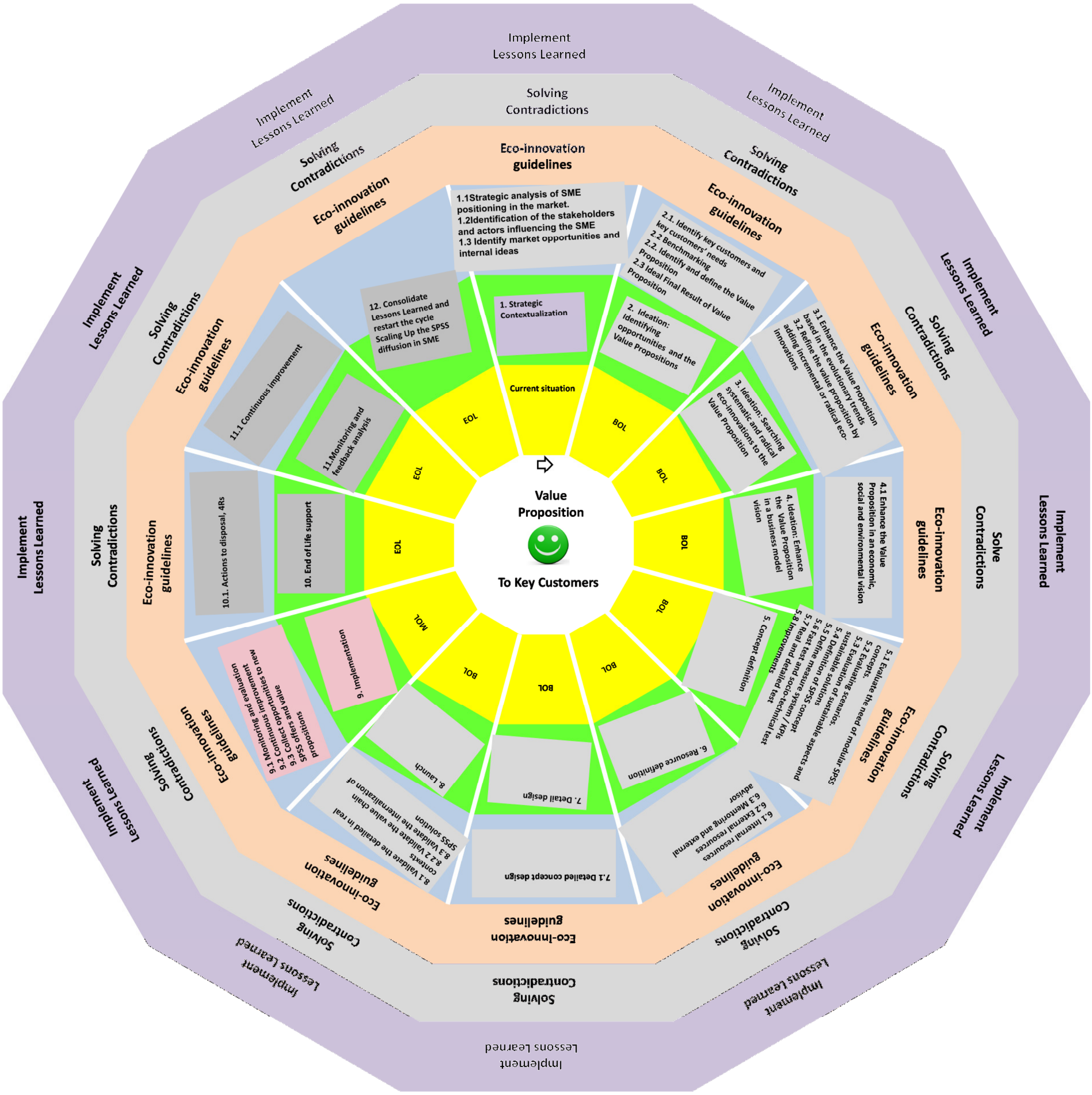

Fig. 8. Version M4 of method proposed

The second suggestion given by experts was regarding to the internal structure and interactions of method M3. In this sense, was suggesting realized a more detailed step-by-step of Fig. 7, resulting in a more structured format as can be seen in Fig. 9. Considering the opinion of experts the method is a well organized artefact and represents a contribution to the research field.

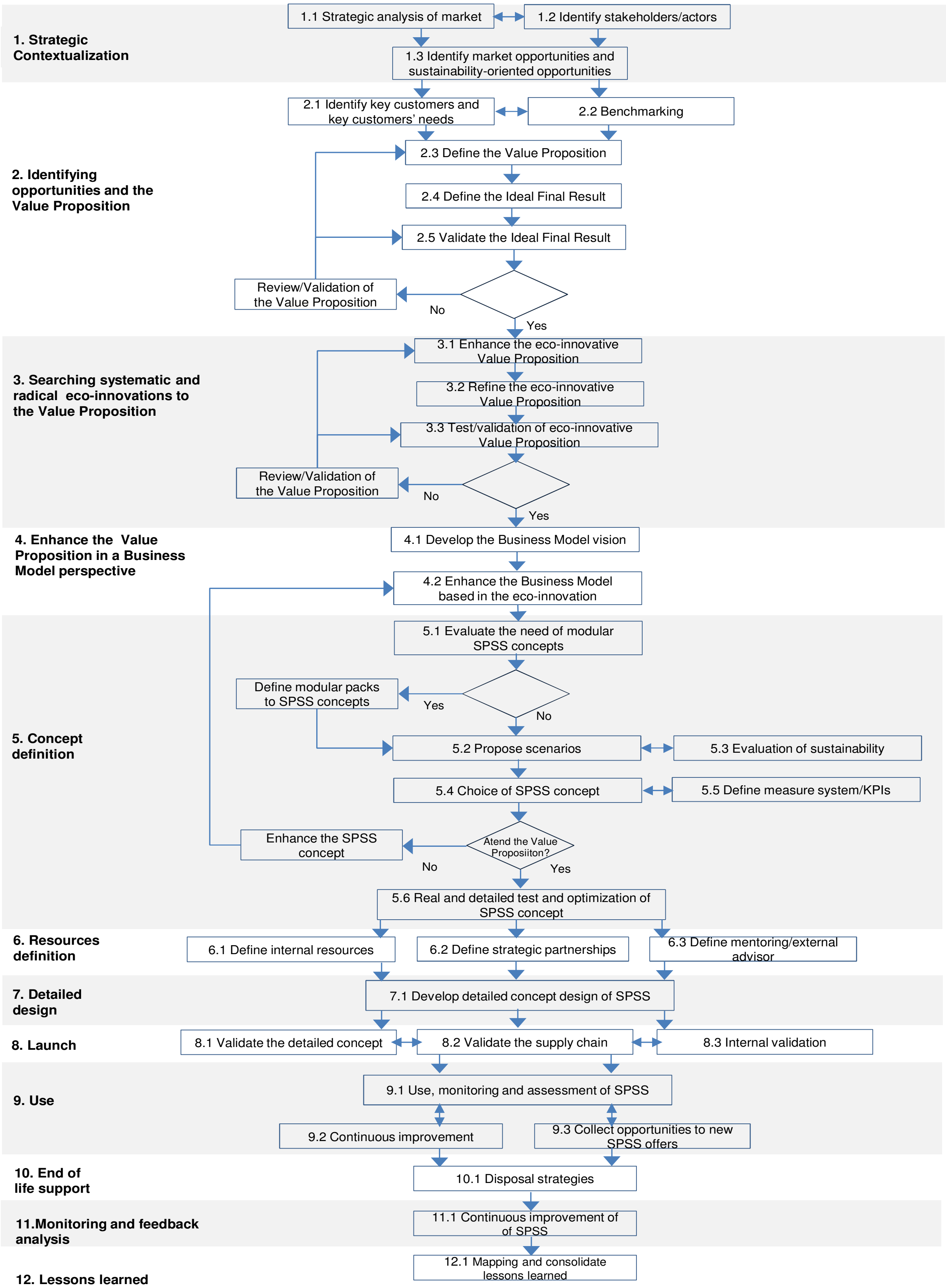

Fig. 9. Internal structure and interactions of method M4

Finally, as result of successive steps of validation process, and based on findings from literature, the reference method nnovation oriented eco-innovation to support the design of SPSS proposals to manufacturing SMEs was proposed.

8.5 Discussion and Conclusions

The purpose of this study was apply focus group methodology complementing the findings from Chapter 2, 3, 4, and 5 aiming develop a reference method supporting the design of SPSS proposals in manufacturing SMEs. Hence, three focus groups were realized based on the previous results of this thesis.

The first Focus Group was organized having as start point the research gaps from identified mainly in the papers 1, 2, 4, 5 and 6, as well as, the version M1 of proposed method developed from results of systematic literature review study by Cavalieri and Pezzotta (2012). The objective of this Focus Group was to define the appropriate stages, tasks and tools for the life cycle of the PSS design (BOL, MOL, EOL) adapted to the manufacturing SMEs. The main results achieve were the suggestion of appropriate stages, tasks and tools for the life cycle of the PSS design suited to the manufacturing SMEs. As consequence, these results were used as bottotm line to develop the version M2 of proposed method.

The second Focus Group was organized having as start point the research gaps from the papers 1, 2, 4, 5 and 6, as well as, the study by Yang et al. (2017). The main purpose was to extend the main categories of sources of value uncaptured and the detailed aspects across the PSS life cycle to SMEs and also to define strategies to increase the added value in each phase of PSS life cycle suited to SMEs. These results also were applied in the development of version M2. The findings of this Focus Group permitted to obtain new categories of sources of value uncaptured and detailed aspects to SMEs were complemented. In this sense, this Focus Group do a contribution to the literature extending the study by Yang et al. (2017). Finally, the findings also were used as bottom line to develop the eco-innovation elements to the version M2 of proposed method.

After the development of M2, the third Focus Group was conducted with the following objectives: (i) to validate and insert in M2 new elements of value addition to customers in a sustainable perspective (environmental, social and economic); (ii) to validate the general architecture among the actors of the method and proposed new connections/interactions; (iii) to validate and improve method M2 defining new/modified phases, tasks, tools and interactions. As main results, was possible to obtain new elements of value addition to customers, was validated the general architecture between the actors and interactions and new phases, tasks, tools was suggested. The content analyse of these findings and the incorporation of these results permitted the proposition of version M3 of reference method. Finnally a validation with experts was conducted obtained a version M4 of reference method to support the design of SPSS proposals in manufacturing SMEs. This reference method fills the research gaps pointed by literature as was detailed in the previous chapters. Further research might realize empirical validation of this method in manufacturing SMEs in order o obtain a generalization and new enhacement.

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REFERENCES

Cavalieri, S., Pezzotta, G. 2012. Product–Service Systems Engineering: State of the art and research challenges, Computers in Industry, 63 (4), 278–288.

Dresch, A., Lacerda, D.P., Antunes Jr., J. A. V. 2015. Design Science Research:A Method for Science and Technology Advancement. Springer. pp.161.

European Commission. 2011. Minimizing Regulatory Burden for SMEs. Adapting EU Regulation to the Needs of Micro-Enterprises. Final report. European Commission: Brussels, Belgium, 2011.

Hennink, M. M. 2007. International Focus Group Research. Cambridge University Press. 277p.

Moore, S., Manring, S. 2009. Strategy development in small and medium sized enterprises for sustainability and increased value creation, Journal of Cleaner Production 17: 276–282.

Orloff, D., Heinz, S. M. 2015. Sustainable product service systems in small and medium enterprises - from a case study on textile leasing to a Design Thinking Workshop for Sustainable Product Service System Development for Sustainable Product-Service System Development. Master Thesis in Sustainability Science. Universitat Luneburg. 160 p.

Pardo, H.R.J. 2012. Designing Sustainable Product Service Systems: a business framework for SME implementation. Doctor of Philosophy, Loughborough University, 358 p.

Reichertz, J. 2014. Induction, Deduction, Abduction, 123-135. Chapter in:Flick, Uwe (org). The SAGE Handbook of Qualitative Data Analysis, SAGE Publications Ltd; 1 edition, 664 p.

Schreier, M. 2014. Qualitative Content Analysis. Chapter in:Flick, Uwe (org). The SAGE Handbook of Qualitative Data Analysis, SAGE Publications Ltd; 1 edition, 664 p.

Yang, M., Evans, S., Vladimirova, D., Rana, P. 2017. Value uncaptured perspective for sustainable business model innovation. Journal of Cleaner Production 140: 1794 – 1804.

Yang, M., Vladimirova, D., Rana, P., Evans, S., 2014. Sustainable value analysis tool for value creation. Asian J. Manag. Sci. Appl. 1 (4), 312 e 332.

Xing, K., Ness, D. 2016. Transition to product-service systems: principles and business model. Procedia CIRP 47: 525–530.

Appendix A
Focus Group 1 – Terminology and contextualization document

Topic: PSS design business models in SMEs

Main objective of focus group: The guiding question to be explored in this focused group is: What would be the main phases, tasks/activities and engineering tools used in each phase, suited to SMEs context to successful PSS design implementation?

Specific terminology, definition and context:

1. PSS are considered as integrated solutions where products and services are mixed together to satisfy the customer’s needs, often in very innovative ways that demand deep transformation in the organization including the ownership of the offer and with a clear potential to be sustainable systems.

In this way, PSS can contribute to achieving a sustainable business supported by moving the focus from producing and selling physical products to designing and selling systems of services and products that together can satisfy the user’s needs with less or more efficient use of resources and usually offer longer life cycles. These integrated solutions could present benefits for the three dimensions of the bottom line, which are environment, society and economy.

2. Service Engineering (SE) is an emerging technical discipline whose foremost aim is to provide a "systematic development and design of services using suitable models, methods and tools as well as the management of the service development process". SE aims to apply the engineering-scientific know-how to develop Service Systems and PSS in a systematic and methodological way. A SE process model specifies the sequences and the iterations of the process phases and the related engineering activities.

2.1 Systems Engineering is conceived as an interdisciplinary approach and means to enable the realisation of a system and its constituent entities, interacting with the most relevant stakeholders and actors throughout the system’s life cycle.

From these definitions in the PSS context, the **fundamental elements to be considered for a complete understanding of PSS Engineering** are:

2.2 Entities:

Real or abstract, tangible or intangible, whose relationship forms the PSS as a whole. System content (tangible, intangible) and channel are the main entities defining a PSS. The channel is used to transfer, amplify and control the contents. Considering the PSS definition by Mont, the channel can be further split into networks of companies, that may jointly fulfil customer needs, and existing collective and private infrastructures.

2.3 Life cycle:

An exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases.

A successful offering and realisation of a PSS extends the involvement and responsibility of the provider throughout the entire life cycle: from the design and realisation (Beginning of Life, BOL), to the usage and maintenance (Middle of Life, MOL) and the dismission (End of Life, EOL). Manufacturing firms, in order to increase revenues, have to provide services during the complete life cycle of the physical product, such as operations on the installed base. A successful offering and realisation of a PSS extends the involvement and responsibility of the provider throughout the entire life cycle.

2.3.1 Beginning Of Life (BOL): including design and manufacturing: identifying requirements, defining specifications, doing a more and more detailed design, developing prototypes and performing tests, and finally manufacturing.

2.3.2 Middle Of Life (MOL): the product is in the hands of the customer, who uses it, and is supported by the manufacturer or providers for maintenance. It also includes external logistic, distribution.

2.3.3 End Of Life (EOL): the product is retired or upgraded by the manufacturer and disposed by the customer. Products are retired in order to be recycled. EOL is the phase where products are collected, disassembled, refurbished, recycled, reassembled, reused or disposed.

2.4 Actors:

SE require designing business architectures in which networks of customers, suppliers and alliance partners maintain consistent levels of quality, while allowing for minor variances in ends and means. To reach this purpose, the involvement of the value chain actors is one of the main pillars of the PSS development. It is also important to define and understand the role of different actors inside and outside the process development along the whole life cycle of a system.

PSS are forcing a new understanding of relationships, and many stakeholders are involved in the provision of sustainable and ecological solutions. However, to consider customers and stakeholders as key resources, the development process has to be redefined, and new activities must be encouraged throughout the life cycle phases. The aim in service development is to create prerequisites for long-term profitable customer relations and to attract and keep customers who are satisfied and loyal along the different life cycle phases [20].

The **main actors** to be involved in a PSS are:

2.4.1 Customer/End-User: to engineer the Product–Service, customers' needs and diversity have to be known for the identification of the requirements throughout the PSS life cycle phases. The customer can be involved either in an active, as co-designer or co-producer, or in a passive way, as a mere source of information.

2.4.2 Channel: all the actors involved along the channel need to be considered within the engineering process due to their intermediary role between the manufacturer and the customer.

2.4.3 Society and environment: refers to the actors operating in the PSS business ecosystem. In our understanding, they can be related to laws and regulations, which allow a proper functioning of the ecosystem.

3. Successful PSS design model Guidelines:

Author(s)	**PSS Guidelines**
Mont (2002)	• Minimise the environmental impacts of the customers' needs • Promote closed material cycles • Facilitate innovation beyond the incremental level • Improve the relationship with the customer and require a higher level of customer involvement
Tukker (2004)	• Provide integrated and customized solutions • Build unique relationships with clients • Support faster innovative approaches

	• Create added value throughout the stakeholder value chain • Fulfil customer needs with minimal material use and emissions
Tan et al. (2006)	• Customer and stakeholders activities as mediators of value instead of a product • Customers as co-producers of value • Partnerships as a source of new knowledge and competencies • Appropriate mix of products and services for new market relationships
Baines et. al. (2007)	• Create added value by increasing services elements (value-in-use), customization and quality • Require manufactures and services providers to extend their involvement and responsibility in the solution life cycle (e.g. maintenance, take-back, recycling, re-use, remanufacture and refurbishment) • Lead to reduced resource use and waste generation • Promote the involvement with the customer and other stakeholders.
Cavalieri and Pezzotta (2012)	• An exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases. • The importance of involving customers and users as co-designers and part of the service results along the PSS life cycle
Muto, Kimita and Shimomura (2015)	• In the design of actor network the PSS provider must consider that the PSS delivery process needs to cover not only the phase of use of the products and/or services, but also other customer activities. • In order to prepare resources for customers, new and varying types of actors must be involved as a part of a network. • PSS designers need to consider the benefits and risks among the stakeholders involved in the network • PSS designers need to manage the design expertise gained thorough PSS design or reuse resources to another PSS business. This is called continuous improvement of the PSS design cycle. • PSS designers need to repeat the service design cycle and continuously improve the design solution, because service includes number of human factors which have influence on service development.
Xing and Ness (2016)	• The product is of a relatively high market value, or relatively high selling prices in comparison with other similar products, which can make it worth for the company to take up stewardship over the life-cycle of the product. • The product is durable and of a long physical life which warrants the possibility for multiple use. The product and its components will be designed for durability and reliability to minimise the need for repair and enable use life extension. • The product will be designed with minimal footprint • The product's structure will be modular to facilitate disassembly, maintenance, reuse, remanufacture and material/component recovery. Design will also enable ease of technological updating/upgrading for function improvements. • The ownership of product will be retained by service provider. As the product is legally owned by the provider, the provider can better exercise 'extended producer responsibility' and devise an appropriate 3Rs (reduce, reuse, and recycle) logistics plan for the product. • There must be some basic service options (e.g. leasing or renting, desktop support, performance monitoring and maintenance contract) and their combinations as building blocks for PSS in place. • The service provider can manage a fleet of products for the customer, leading to increased utilization and improvement of efficiency. • A proper take-back system will be in place to take back products for reuse, remanufacturing or recycling. • The service should contribute to increase of environmental values of ownership. Provision of equipment by service provider should aim for zero waste. • The service will lower the total cost of ownership (cost of procuring, deploying, managing, maintaining and decommissioning).

4. Contextualizing Small and Medium-sized Enterprises (SMEs):

• Small and Medium-sized Enterprises (SMEs) are very important in many countries due to the development role they play in the local economy.

• In general, official definition of SMEs varies from country to another.

• SMEs contribute to three main sectors which are agriculture, manufacturing and service sectors.

• The highest majority of SMEs in many of developed and developing countries are that core businesses in the service sector.

• However, increasing market competitiveness in the SMEs sector makes it imperative for these organizations to think of ways that support innovation when resolving their production/service problems.

Some characteristics and advantages/disadvantages of SMEs are:

- Dominant role of the entrepreneur/owner
- Resource poverty (capital, time, knowledge and skilled personnel)
- Flexible organization capacities
- Focus on short term
- Strong local/regional focus and customer needs orientation
- Low degree of formalization

Advantages	Disadvantages
Flexibility of organization	***Financial***
Less bureaucratic	Difficulties attracting venture capital and bank investments
Responsiveness to changing circumstances (technology and market)	Failure of innovation projects may be financially disastrous
Internal communications faster and more efficient	High fixed costs for technological investments and start-up
Owner/manager	***Owner/manager***
Dynamic, entrepreneurial	Poor managerial skills (planning, inadequate delegation, lack of functional expertise or support)
Horizontal leadership style	Dependency on persons for survival
Direct role in innovation as ideas generator	Lack of formalized planning
	Labour
	Difficulties attracting skilled personnel
	Harder to update technological knowledge

Appendix B

Focus Group 2 – Terminology and contextualization document

Topic: PSS design business models in SMEs

Main objective of focus group:

This focus group adopt the study by Yang et al. (2017) as bottom line, in order to:

- To extend the **main categories** of sources of value uncaptured across the PSS life cycle suited to SMEs context, from expert's opinion.
- To extend the **detailed aspects** of sources of value uncaptured across the PSS product life cycle suited to SMEs context, from expert's opinion.
- To define strategies to **increase the added value** in each phase of PSS life cycle suited to SMEs.

1. Specific terminology, definitions and context:

Value

Value is defined, in a Value Management (VM) context, as the relationship between the satisfaction of needs and the resources used in achieving that satisfaction (EN 1325-1:2001)

The increasing of Value in a product, process or service is not necessarily the result of cost reduction. In Value definition (Fig. 1) the symbol a means that the relationship between satisfaction of needs, often called performance and the used resources is only a representation.

$$\boxed{\text{Value} \quad \alpha \quad \frac{\text{Satisfaction of needs}}{\text{Consumption of resources}}}$$

Fig. 1. The concept of Value.

Value is not an absolute measure, but a relative one, and can be differently perceived by the different stakeholders involved in the process (EN 12973, 2001). It is an indicator that enables the comparison between the existing Value with the ones resulting from the VA study proposals. As depicted in Fig. 1 there is a Value increase when the use of resources is lower and/or the satisfaction of needs is higher

A sustainable business model

Is defined by Lüdeke-Freund (2010) as “a business model that creates competitive advantage through superior customer value and contributes to the sustainable development of the company and society”. This recognises that the core of a sustainable business is still creating and delivering customer value but in which the environmental and social benefits are embedded.

Value captured in literature is defined as ‘how the firm generates revenue and profit’ and it includes ‘revenue sources’ and ‘the economics of the business’.

Value uncaptured

Value uncaptured is the set of benefits that could be captured but have not yet been captured. Value uncaptured is not only for customers and the firms, but for all stakeholders, such as end users, suppliers, shareholders, government and partners. Secondly, the value covers not only monetary value, but also wider value for the environment and for society. In this sense, the four forms of value uncaptured applied to sustainable PSS business models are: value surplus, value absence, value missed and value destroyed.

Value uncaptured exists in almost all companies. Some value uncaptured is visible, e.g. waste streams in production, co-products, under-utilised resources, and reusable components of broken products, while often it is invisible, e.g. over capacity of labour, insufficient use of expertise and knowledge.

Value surplus (VS) is value which exists, but is not required. These are things or activities that are more than needed. They are redundant and unnecessary. They can be regarded as waste in a company or unnecessary value delivered to stakeholders. The concept of VS is similar to waste but embodies a broader meaning. It includes not only tangible waste but also intangible waste, such as underutilisation of human resource. It offers higher potential to be turned into value. It exposes avoidable resource consumption and cost. Examples could be wasted heat, waste energy, over production, underutilisation of resources, and unnecessary, repeated work.

Value absence (VA) is value which is required, but does not exist. They are things or activities that are needed but have not been provided. It can be regarded as needs that could have been met but have not yet been met; or as a lack of resource that is needed by the company or its stakeholders. For example this could be a temporary lack of labour, the need for recycling service, the need for experts in certain fields, or the need for a platform. A specific example could be that there is a temporary need for additional warehouse space and workers due to increased production, but the company may not be inclined to buy extra warehouse space or to hire new employees just for this short busy period. In this case, the need for additional warehousing and labour can be regarded as a value absence.

Value missed (VM) is value which exists and is required, but is not exploited. It could create more value but it does not. It is currently squandered or inadequately captured by the current business model. It can be regarded as waste with high potential to be used. It does not bring about negative outcomes but it reduces value that could be created. Examples are underutilization of by-products and co-products, underutilised assets and resources, and inefficient use of human resources.

Value destroyed (VD) is value with negative outcomes. It causes negative effects for the company or other stakeholders, and is the negative outcome of the current business model. It can be seen as damage to the planet, people and profits. In the context of sustainability, value destroyed refers particularly to damage to the environment and to society. Examples include depletion of non-renewables, pollution, poor product and service quality, bad working conditions and health and safety problems.

2. Contextualizing Small and Medium-sized Enterprises (SMEs):

- Small and Medium-sized Enterprises (SMEs) are very important in many countries due to the development role they play in the local economy.
- In general, official definition of SMEs varies from country to another.
- SMEs contribute to three main sectors which are agriculture, manufacturing and service sectors.
- The highest majority of SMEs in many of developed and developing countries are that core businesses in the service sector.

• However, increasing market competitiveness in the SMEs sector makes it imperative for these organizations to think of ways that support innovation when resolving their production/service problems.

Some characteristics and advantages/disadvantages of SMEs are:

- Dominant role of the entrepreneur/owner
- Resource poverty (capital, time, knowledge and skilled personnel)
- Flexible organization capacities
- Focus on short term
- Strong local/regional focus and customer needs orientation
- Low degree of formalization

Advantages	Disadvantages
Flexibility of organization	***Financial***
Less bureaucratic	Difficulties attracting venture capital and bank investments
Responsiveness to changing circumstances (technology and market)	Failure of innovation projects may be financially disastrous
Internal communications faster and more efficient	High fixed costs for technological investments and start-up
Owner/manager	***Owner/manager***
Dynamic, entrepreneurial	Poor managerial skills (planning, inadequate delegation, lack of functional expertise or support)
Horizontal leadership style	Dependency on persons for survival
Direct role in innovation as ideas generator	Lack of formalized planning
	Labour
	Difficulties attracting skilled personnel
	Harder to update technological knowledge

3. Successful PSS design model Guidelines:

Author(s)	PSS Guidelines
Mont (2002)	• Minimise the environmental impacts of the customers' needs • Promote closed material cycles • Facilitate innovation beyond the incremental level • Improve the relationship with the customer and require a higher level of customer involvement
Tukker (2004)	• Provide integrated and customized solutions • Build unique relationships with clients • Support faster innovative approaches • Create added value throughout the stakeholder value chain • Fulfil customer needs with minimal material use and emissions
Tan et al. (2006)	• Customer and stakeholders activities as mediators of value instead of a product • Customers as co-producers of value • Partnerships as a source of new knowledge and competencies • Appropriate mix of products and services for new market relationships
Baines et. al. (2007)	• Create added value by increasing services elements (value-in-use), customization and quality • Require manufactures and services providers to extend their involvement and responsibility in the solution life cycle (e.g. maintenance, take-back, recycling,

	re-use, remanufacture and refurbishment) • Lead to reduced resource use and waste generation • Promote the involvement with the customer and other stakeholders.
Cavalieri and Pezzotta (2012)	• An exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases. • The importance of involving customers and users as co-designers and part of the service results along the PSS life cycle
Muto, Kimita and Shimomura (2015)	• In the design of actor network the PSS provider must consider that the PSS delivery process needs to cover not only the phase of use of the products and/or services, but also other customer activities. • In order to prepare resources for customers, new and varying types of actors must be involved as a part of a network. • PSS designers need to consider the benefits and risks among the stakeholders involved in the network • PSS designers need to manage the design expertise gained thorough PSS design or reuse resources to another PSS business. This is called continuous improvement of the PSS design cycle. • PSS designers need to repeat the service design cycle and continuously improve the design solution, because service includes number of human factors which have influence on service development.
Xing and Ness (2016)	• The product is of a relatively high market value, or relatively high selling prices in comparison with other similar products, which can make it worth for the company to take up stewardship over the life-cycle of the product. • The product is durable and of a long physical life which warrants the possibility for multiple use. The product and its components will be designed for durability and reliability to minimise the need for repair and enable use life extension. • The product will be designed with minimal footprint • The product's structure will be modular to facilitate disassembly, maintenance, reuse, remanufacture and material/component recovery. Design will also enable ease of technological updating/upgrading for function improvements. • The ownership of product will be retained by service provider. As the product is legally owned by the provider, the provider can better exercise 'extended producer responsibility' and devise an appropriate 3Rs (reduce, reuse, and recycle) logistics plan for the product. • There must be some basic service options (e.g. leasing or renting, desktop support, performance monitoring and maintenance contract) and their combinations as building blocks for PSS in place. • The service provider can manage a fleet of products for the customer, leading to increased utilization and improvement of efficiency. • A proper take-back system will be in place to take back products for reuse, remanufacturing or recycling. • The service should contribute to increase of environmental values of ownership. Provision of equipment by service provider should aim for zero waste. • The service will lower the total cost of ownership (cost of procuring, deploying, managing, maintaining and decommissioning).

Appendix C
Focus Group 3 – Terminology/contextualization document

Topic: Sustainable PSS design business models in SMEs

Main objective of focus group: The objectives of this focused group are:

- To validate and insert new **value addition** elements in a sustainable perspective (environmental, social and economic) to customer in the current version of the method.
- To validate the general **architecture** among the actors of the method and proposed **new connections/interactions**.
- To evaluate the current version of the method suggesting **new phases, tasks, tools** i.e. In this sense, what would be the main phases, tasks/activities and engineering/management tools used in each phase, suited to SMEs context to successful SPSS design implementation?

Specific terminology, definition and context:

1. PSS are a specific type of value proposition that a business (network) offers to (or co-produces with) its clients and one definition of PSS is 'a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs' (Tukker, 2015)

1.1 Sustainable PSS (SPSS): To Barquet et al. (2016) SPSS **business model is an approach to achieve benefits in the three dimensions of sustainability**. Through efficient resource utilization and dematerialization, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage.

2. Service Engineering (SE) is an emerging technical discipline whose foremost aim is to provide a "systematic development and design of services using suitable models, methods and tools as well as the management of the service development process" (Aurich, et al., 2010).

SE aims to apply the engineering-scientific know-how to develop Service Systems and PSS in a systematic and methodological way (Aurich, et al., 2010; Bullinger, 2003). A SE process model specifies the sequences and the iterations of the process phases and the related engineering activities (Aurich, et al., 2010).

2.1 Systems Engineering is conceived as an interdisciplinary approach and means to enable the realisation of a system and its constituent entities, interacting with the most relevant stakeholders and actors throughout the system's life cycle (INCOSE, 2011).

From these definitions in the PSS context, the **fundamental elements to be considered for a complete understanding of PSS Engineering** are:

2.2 Entities:

Real or abstract, tangible or intangible, whose relationship forms the PSS as a whole. System content (tangible, intangible) and channel are the main entities defining a PSS (Sakao and Shimomura, 2007). The channel is used to transfer, amplify and control the contents. Considering the PSS definition by Mont (2004), the channel can be further split into networks of companies that may jointly fulfil customer needs, and existing collective and private infrastructures.

2.3 Life cycle:

An exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases.

A successful offering and realisation of a PSS extends the involvement and responsibility of the provider throughout the entire life cycle: from the design and realisation (Beginning of Life, BOL), to the usage and maintenance (Middle of Life, MOL) and the dismission (End of Life, EOL) (Wild et al., 2009; Aurich et al., 2010).

Manufacturing firms, in order to increase revenues, have to provide services during the complete life cycle of the physical product, such as operations on the installed base (Oliva and. Kallenberg, 2003). A successful offering and realisation of a PSS extends the involvement and responsibility of the provider throughout the entire life cycle (Wild et al., 2009; Aurich et al., 2010; Lindahl et al., 2006).

2.3.1 Beginning Of Life (BOL): including design and manufacturing: identifying requirements, defining specifications, doing a more and more detailed design, developing prototypes and performing tests, and finally manufacturing (Baveja et al., 2004).

2.3.2 Middle Of Life (MOL): the product is in the hands of the customer, who uses it, and is supported by the manufacturer or providers for maintenance. It also includes external logistic and distribution (Baveja et al., 2004).

2.3.3 End Of Life (EOL): the product is retired or upgraded by the manufacturer and disposed by the customer. Products are retired in order to be recycled. EOL is the phase where products are collected, disassembled, refurbished, recycled, reassembled, reused or disposed (Baveja et al., 2004).

2.4 Actors:

SE require designing business architectures in which networks of customers, suppliers and alliance partners maintain consistent levels of quality, while allowing for minor variances in ends and means. To reach this purpose, the involvement of the value chain actors is one of the main pillars of the PSS development. It is also important to define and understand the role of different actors inside and outside the process development along the whole life cycle of a system (Wild et al., 2009).

PSS are forcing a new understanding of relationships, and many stakeholders are involved in the provision of sustainable and ecological solutions. However, to consider customers and stakeholders as key resources, the development process has to be redefined, and new activities must be encouraged throughout the life cycle phases. The aim in service development is to create prerequisites for long-term profitable customer relations and to attract and keep customers who are satisfied and loyal along the different life cycle phases (Sundin, 2009).

The **main actors** to be involved in a PSS are (Sundin, 2009; Mont, 2002):

2.4.1 Customer/End-User: to engineer the Product–Service, customers' needs and diversity have to be known for the identification of the requirements throughout the PSS life cycle phases. The customer can be involved either in an active, as co-designer or co-producer, or in a passive way, as a mere source of information.

2.4.2 Channel: all the actors involved along the channel need to be considered within the engineering process due to their intermediary role between the manufacturer and the customer [62].

2.4.3 Society and environment: refers to the actors operating in the PSS business ecosystem. In our understanding, they can be related to laws and regulations, which allow a proper functioning of the ecosystem (Sundin, 2009).

3. Successful PSS design model Guidelines or benefits:

Author(s)	PSS Guidelines
Mont (2002)	• Minimise the environmental impacts of the customers' needs • Promote closed material cycles • Facilitate innovation beyond the incremental level • Improve the relationship with the customer and require a higher level of customer involvement
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Cavalieri and Pezzotta (2012)	• An exact separation between product and service elements is no longer feasible, neither during the design and development nor during the delivery and use phases. • The importance of involving customers and users as co-designers and part of the service results along the PSS life cycle
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Xing and Ness (2016)	• The product is of a relatively high market value, or relatively high selling prices in comparison with other similar products, which can make it worth for the company to take up stewardship over the life-cycle of the product. • The product is durable and of a long physical life which warrants the possibility for multiple use. The product and its components will be designed for durability and reliability to minimise the need for repair and enable use life extension. • The product will be designed with minimal footprint • The product's structure will be modular to facilitate disassembly, maintenance, reuse, remanufacture and material/component recovery. Design will also enable ease of technological updating/upgrading for function improvements. • The ownership of product will be retained by service provider. As the product is legally owned by the provider, the provider can better exercise 'extended producer responsibility' and devise an appropriate 3Rs (reduce, reuse, and recycle) logistics plan for the product. • There must be some basic service options (e.g. leasing or renting, desktop support, performance monitoring and maintenance contract) and their combinations as building blocks for PSS in place. • The service provider can manage a fleet of products for the customer, leading to increased utilization and improvement of efficiency. • A proper take-back system will be in place to take back products for reuse, remanufacturing or recycling. • The service should contribute to increase of environmental values of ownership. Provision of equipment by service provider should aim for zero waste. • The service will lower the total cost of ownership (cost of procuring, deploying,

	managing, maintaining and decommissioning).

4. Contextualizing Small and Medium-sized Enterprises (SMEs):

- Small and Medium-sized Enterprises (SMEs) are very important in many countries due to the development role they play in the local economy.
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- However, increasing market competitiveness in the SMEs sector makes it imperative for these organizations to think of ways that support innovation when resolving their production/service problems.

Some characteristics and advantages/disadvantages of SMEs are:

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- Resource poverty (capital, time, knowledge and skilled personnel)
- Flexible organization capacities
- Focus on short term
- Strong local/regional focus and customer needs orientation
- Low degree of formalization

Advantages	Disadvantages
Flexibility of organization Less bureaucratic Responsiveness to changing circumstances (technology and market) Internal communications faster and more efficient	***Financial*** Difficulties attracting venture capital and bank investments Failure of innovation projects may be financially disastrous High fixed costs for technological investments and start-up
Owner/manager Dynamic, entrepreneurial Horizontal leadership style Direct role in innovation as ideas generator	***Owner/manager*** Poor managerial skills (planning, inadequate delegation, lack of functional expertise or support) Dependency on persons for survival Lack of formalized planning ***Labour*** Difficulties attracting skilled personnel Harder to update technological knowledge

5. Guidelines and Best Practices to Successful SPSS Transition n SMEs

Author(s)	Guidelines and Best Practices to Successful SPSS Transition n SMEs

Lelah et al.	• First, the SME must clearly formulate the problem it faces. • Often starting with a small part of the business and then extending to the whole organization. Cover practically the whole business structure, including relationships within the value network, organizational culture and mental models.
Xing and Ness	• To achieve PSS transition, careful design of business cases is required to increase resource efficiency, while even more consideration is necessary to increase social sustainability via affordability and generating increased employment. • The product: is of a relatively high market value or relatively high selling prices in comparison with other similar products, is durable/long physical life, designed with minimal footprint and with modular structure. • The service: The ownership of product will be retained by service provider. There must be some basic service options (e.g. leasing or renting, desktop support, performance monitoring and maintenance contract) and their combinations as building blocks for PSS in place. The service contributes to increase of environmental values of ownership and will lower the total cost of ownership. The service provider can manage a fleet of products for the customer. A proper take-back system will be in place. • Management: There should be a champion in the client company. Adopt change management principles (e.g. commitment through conveying the value of PSS across the client). Employees (e.g. procurement officers, marketing personnel) should undertake training in new skills associated with PSS. Reward systems should be in place. Monitor and report the operation performance of the fleet in meeting service requirements. Measure and monitor environmental and economic performance in different operation and business scenarios. • Business Model: Define who customers are, what customer values to serve, what processes (both internal and external) to engage and interact with customers, what resources and assets to possess and utilise, what and how revenue can be generated, and associated cost implications. • Needs to be market-oriented and customer-focused. • Able to address a particular customer value network and to fulfill functional, economic, environmental and social demands.
Tonelli et al.	• Risk analysis, cost analysis, profit analysis and business sustainability analysis should be carried out in order to economically, financially and environmentally characterize the possible PSS strategies. • Availability of HR/Infrastructural/ICT competences in SME. • Develop a marketing plan to promote the new business model in the market, both versus existing and new customers.
Lelah et al. (2012)	• SMEs need support from an ICT backbone facilitating communication of data within the network. • Co-creation of value by user is a key factor for PSS and it is important to provide a basis for exploring possibilities across the supply chain network
Sundin et al.	• Sustainability indicators have been adjusted to each SME' needs according sector activity. • The number of indicators need be limited much as possible to minimize extra work. • The PSS offer and indicators need be developed in cooperation with currents and future customers.
Hernandez-Pardo et al.	• Integrate Design and ICT to virtualization in the production and evaluation of prototype, to recovery, repair and resale of products, to develop a collaborative platform between SMEs. • Use ICT based system to the optimization of the production improving the decision making.
Hernandez-Pardo et al. 2013	• Use ongoing projects as a starting point for a transformation toward SPSS.

Appendix D – Forms to Focus Group 1
Form 1 - Phase Analysis

PSS Life Cycle	Phases of PSS design	Proposition/inclusion/exclusion of Phases by specialist
Beginning Of Life	1. Requirements generation	
	2.Requirements identification	
	3. Requirements analysis	
	4. Concept generation	
	5. Concept evaluation	
	6. Concept development and evaluation	
	7.Embodiment design and evaluation	
	8. Detailed design	
	9.Test(prototyping or simulating)	
	10. Final design	
	11. Implementation and measure	
Mid le Of Life	12. Use and maintenance	
	13. Monitoring and evaluation	
End Of Life	14. End of life support	
	15. Monitoring and feedback analysis	

Form 2 - Analysis of tasks, activities and tools to each phase of PSS design

PSS Life cycle	Phase of PSS	Tasks	Proposition/inclusion/exclusion of tasks by expert and suited tool to realize the task
Begin ning Of Life	1.Requirements generation	1.1Strategic analysis of market. 1.2 Identification of the actors involved 1.3 Exploring market opportunities. 1.4 Identify the value proposition to customer.	
	2.Requirements identification	2.1. Customer demands identification. 2.2. Describing and define the value proposition to the customer. 2.3 Define requirements for the PSS	
	3.Requirements analysis	3.1. PSS idea development.	
	4. Concept generation	4.1. Generation of concept.	
	5. Concept evaluation	5.1. Evaluation of concept.	
	6.Concept development and evaluation	6.1. PSS concept development. 6.2. Definition and graphical representation of PSS structure, layers, interfaces and subsystems.	
	7.Embodiment design and evaluation	7.1. Realize the integration of subsystems	
	8. Detailed design	8.1 Modelling of PSS	
	9.Test(prototyping or simulating)	9.1 PSS test 9.2. Evaluation of value proposition to customer.	
	10. Final design	10.1. To improve the PSS design 10.2 Validation and Definition of concept 10.3 Define the performance measure system	
	11.Implementation and measure	11.1 Implementation of PSS 11.2 Measure performance	
Mid le Of Life	12. Use and maintenance	12.1 Apply maintenance and recovery strategies	
	13. Monitoring and evaluation	13.1 Monitoring and evaluation of measure system of PSS	
End Of Life	14. End of life support	14.1. Actions to disposal, recycle, reuse etc	
	15.Monitoring and feedback analysis	15.1 Continuous improvement actions	

Appendix E – Forms to Focus Group 2

Form 1 - New agile/responsive sources of VU (economic, environmental and social) in the life cycle of PSS in SMEs

<table>
<tr><td colspan="2">Value surplus (VS) is value which exists, but is not required.</td><td colspan="2">Value absence (VA) is value which is required, but does not exist</td><td>Value missed (VM) is value which exists and is required, but is not exploited</td><td>Value destroyed (VD) is value with negative outcomes</td></tr>
<tr><th colspan="6">GIVING THE FOLLOW SOURCES AS THE PSS LIFE CYCLE AND ALSO BASED IN YOUR BACKGROUND IN PSS:</th></tr>
<tr><th colspan="2">BOL - VU</th><th colspan="2">MOL - VU</th><th colspan="2">EOL - VU</th></tr>
<tr><td colspan="2">Design
Production
Operations management
Customer needs
Human resources
Contracts
R&D
Finance
Planning
Knowledge & technology</td><td colspan="2">Customers' value uncaptured
Human resources
Operations management
Service data
Co-products or by-products
Products' products
Services
Customer needs
Need for a platform
Delivery
Conflicts over service contracts
Risks
Wasted resources and energy</td><td colspan="2">Recycle
Reuse
Remanufacture</td></tr>
<tr><th colspan="6">WRITE BELOW 3 OR MORE NEW CATEGORIES TO SOURCES OF VU AND SIGN THE VU TYPE:</th></tr>
<tr><td>BOL-VU</td><td>VS, VA, VM, VD ?</td><td>MOL-VU</td><td>VS, VA, VM, VD ?</td><td>EOL-VU</td><td>VS, VA, VM, VD ?</td></tr>
</table>

Form 2 - New agile/responsive aspects for the sources of VU (economic, environmental and social)

BOL-VU	Aspects	New agile/responsive aspects
Design	Production Operations management Customer needs Human resources Contracts R&D Finance Planning Knowledge & technology	
Production	Over procurement or too early procurement Poor production technology The seven wastes from lean production Pollution (e.g. noise) Quality problems	
Operations management	Poor flexibility Bad mechanism for assessing rewards and penalties Bad project time management Inefficient inter-department collaboration and resource sharing Poor execution ability Insufficient use of information management systems Reluctance to adopt new management systems Unable to adapt to new technology and products Inefficient workflow	
Customer needs	Unknown potential customers Potential customer needs Future customer needs Unclear customer needs Overpromising to meet customer needs	
Human resources	Excess capacity of managers, designers, production workers Lack of excellent human resources Insufficient and inefficient use of labour	
Contract	Low-profit contracts Unclear service contracts	
R&D	Lack of R&D in basic scientific research Lack of R&D into products' products Lack of IP protection	
Finance	High initial investment and low profits	

Planning	Unclear strategic plan	
Knowledge & technology	Lack of knowledge and technologies Wasted knowledge, technology, experience and skills	

MOL-VU	**Aspects**	**New agile/responsive aspects**
Customers' value uncaptured	Customers' wasted resources Customers' waste from products, co-products & by-products Customers' unprofessional use of products Customers' pollution Customers' poor ability in identifying value uncaptured Customers' missed applications for products Insufficient communication between customers and manufacturers Customers' production waste	
Human resource	Excess capacity of service workers Insufficient and inefficient use of service workers Lack of excellent human resources Inefficient communication between workers Repeated work	
Operations management	Lack of regulations for operational management Inefficient workflows (e.g. time, money and human resources wasted in workflows) Service scheduling problems Unnecessary waste in operations Poor flexibility Low operational efficiency Poor mechanism for rewards and penalties Poor execution ability Inefficient inter-department collaboration and resource sharing Inefficient communication between service workers, designers and producers	
Service data	Lack of technology, expertise and knowledge on using data Inefficient and insufficient use of service data (done manually) Missed value from historical service data relating to existing customers Inefficient service arrangements Limited access to some services	
Co-products or by-products	Insufficient use of co- and by-products Unknown applications for co- and by- products Unable to use co- and by- products	

Products' products	Missed applications for products' products Unknown applications for products' products	
Service	Excess service (e.g. unnecessary services, idle service workers, too much investment in service resources) Poor service effectiveness and efficiency Missed service opportunities Lack of service experience Service scheduling problems (e.g. who, when and how many workers to send) Invalid services No calculation or control of service cost Poor service quality Low service charges Lost or missed business opportunities during service Inefficient allocation of service personnel Service tasks too detailed Ineffective service evaluation system	
Customer needs	Unknown customer needs (e.g. real needs, potential needs, hidden needs and future needs) Inaccurate understanding of customer needs Changes in customer needs Unclear customer needs	
Need for a platform	Need for a platform to sell the collected waste Need for a platform to enter new industrial sectors	
Delivery	Delays in delivery Missing components in packaging Sending wrong products or components Late deliveries	
Conflicts over service contracts	Difficulty in judging responsibilities in relation to service contracts	
Risks	Market risks Policy risks	
Waste of resource and energy	Waste of mechanical work Waste of energy (e.g. electricity, heat, cold energy, hot water, cold water and steam) Underutilised resources (e.g. underutilised assets) Oil leaks Lack of freedom to use all this waste since it needs agreement from the customer	
Others	Unexpected problems during service Lost customer loyalty Pressure from retailers	

EOL-VU	Aspects	New agile/responsive aspects
Recycle	No or little recycling Lack of awareness and knowledge of recycling Valuable materials in discarded products Low-value disposal of recycled products No customer demand for recycling Lack of recycling guidance and methods	
Reuse	Idle, usable, re-purchased old products Insufficient use of usable old products Usable products discarded by customers Low-value disposal of usable products and components Poor customer acceptance of reuse of products Small market for used products	
Remanufacture	No or little remanufacturing Lack of awareness and knowledge of remanufacturing Lack of capacity to undertake remanufacturing Need for low-cost remanufacturing technology No customer demand for remanufacturing Low acceptance by customer of remanufactured products Lack of remanufacturing guidance and methods	

Form 3 - New sources of VU (economic, environmental and social) X activities and tasks

PSS Life cycle	Phase of PSS	Tasks	NEW CATEGORIES OF THE SOURCES OF VU	TOOLS
Beginning Of Life	1.Requirements generation	1.1Strategic analysis of market. 1.2 Identification of the actors involved 1.3 Exploring market opportunities. 1.4 Identify the value proposition to customer.		
	2.Requirements identification	2.1. Customer demands identification. 2.2. Describing and define the value proposition to the customer. 2.3 Define requirements for the PSS		
	3.Requirements analysis	3.1. PSS idea development.		
	4. Concept generation	4.1. Generation of concept.		
	5. Concept evaluation	5.1. Evaluation of concept.		
	6.Concept development and evaluation	6.1. PSS concept development. 6.2. Definition and graphical representation of PSS structure, layers, interfaces and subsystems.		
	7.Embodiment design and evaluation	7.1. Realize the integration of subsystems		
	8. Detailed design	8.1 Modelling of PSS		
	9.Test(prototyping or simulating)	9.1 PSS test 9.2. Evaluation of value proposition to customer.		
	10. Final design	10.1. To improve the PSS design 10.2 Validation and Definition of concept 10.3 Define the performance measure system		
	11.Implementation and measure	11.1 Implementation of PSS 11.2 Measure performance		
Mid le Of Life	12. Use and maintenance	12.1 Apply maintenance and recovery strategies		
	13. Monitoring and evaluation	13.1 Monitoring and evaluation of measure system of PSS		
End Of Life	14. End of life support	14.1. Actions to disposal, recycle, reuse etc		
	15.Monitoring and feedback analysis	15.1 Continuous improvement actions		

Appendix F – Forms to Focus Group 3

Form 1 - Structure of proposed method

PSS Life cycle	Phase of PSS	Task/activity	Phase feedback, strong cause-effect relation or strong interaction	Related Tools to realize the task	Focus in Service, Product or PSS
Understanding the current situation	1.Strategic Contextualization	1.1 Strategic analysis of SME positioning in the market. 1.2 Identification of the stakeholders and actors involved influencing the SME 1.3 Identify market opportunities		1.3 SWOT + PESTEL 1.4 Mapping stakeholders- DT 2.3 Value Mapping Tool	P+S
Beginning Of Life	2. Ideation: Identifying opportunities and the Value Propositions	2.1. Identify the key customers and key customers' needs 2.2. Identify and define Value Propositions to the key customers 2.3 Statement of Ideal Final Result of Value Proposition(s) based on key customers and marketing opportunities	9	2.1 Environmental QFD (QFDE) 2.1 Persona + 2.1 - 2.2 Canvas Value Proposition + Constradiction Matrix 2.3 Ideal Final Result	P+S
	3. Ideation: Searching systematic and radical innovations to Value Proposition (s)	3.1 Realize the Benchmarking analysis in the market 3.2. Improving the Value Proposition considering the evolutionary trends involved 3.3 Refine the value proposition by adding incremental or radical innovations	2 looping	3.1. Benchmarking in the market + PSS Benchmarking 3.2. Trend Matrix (DT) + 9 Windows 3.3. 40 IPs to P, S, PSS + 76 Standard Solutions	P, S, and PSS
	4. Ideation: Perfecting the Value Proposition(s)	4.1 Develop and improve the Value Proposition in an economic, social and environmental perspective	2 + 3 in looping	4.1 Business Model Canvas (social, environ, tecno)	P+S
	5. Concept definition	5.1 Generation of modular SPSS concepts. (To consider the existents service already offers by SME.		5.1 – Use a form? 5.2 - 5.3 Assessment of	PSS

		5.2 Evaluation sustainable of alternatives/scenarios. 5.3 Definition/choice of SPSS concept 5.4 Define the performance measure system and KPIs (economic, environmental, social based) 5.5 Realize fast tests or social-technical experiments of SPSS Concept with key customers, Fablabs i.e.		sustainability (economic, environmental, social) current x Value Proposition + Added value (economic, environmental, social) current x Value Proposition + Assessment to Great Value Propositions + IFR 5.4 KPIs matrix 5.5 Fast test, interviews…	
	6. Resource analysis	6.1. Verify the competences, financial resources, internal resources/process and constraints to implementation of SPSS offer. (internal resources: 6.2 Identify and define strategic companies partners/network to develop the SPSS offer, and; 6.3 Define the mentoring/external advisor (consulting, university, governmental programs) to develop the SPSS offer	5.3	6.1 Tool? 6.2 - 6.3 To develop a map of the offer of resources / opportunities?	PSS
	7.Concept development	7.1. Develop the Preliminary Concept design 7.2. Develop detailed concept design (simulation, modelling structure, layers, interfaces, subsystems and integration of subsystems).	5.3	7.1 - 7.2 Blue print + Mapa da jornada + Lego play	P+S
	8. Test	8.1 Realize real and effective test of SPSS offer analysing the empathy/behaviour of users evaluating if Ideal Final Result Value Proposition to customer is met	2.3 5.4	Real customers and employees Socio technical experimentation	PSS

		8.2Implement improvement actions.			
Mid le Of Life	9. Implementation	9.1 Monitoring and evaluation of SPSS (KPIs, user behavior) 9.2 Continuous improvement in the SPSS offer 9.3 Identify opportunities to new SPSS offers	2 5.4		PSS
End Of Life	10. End of Life support	10.1. Implement actions to disposal 4Rs (reuse, remanufacturing, recycle, recovery) etc			P or S
	11.Monitoring and feedback analysis	11.1 Continuous improvement actions	1		P or S
	12. Mapping Lessons Learned in SME on SPSS offer and restart the cycle scaling up SPSS business models in the same or different customer segments				PSS

Please write here your suggestions to improve, strong/weak points or comments:

Appendix H

Form 1- Profile of participants and acceptance of participation (Focus Group 1, 2 and 3)

1. **Name:____**

2. **Time of experience / practice/ research in PSS: ________ years**.

3. **List the activities you develop or develop in the PSS area:**

( ) teaching
( ) research
( ) extension
( ) consulting
( ) orientation academic (Dissertations, Theses)
( ) others_______________________________________

4. **Based on your experience in PSS, please classify your acting:**

Regarding the size of the company:

( ) startups ( ) micro ( ) small ( ) medium ( ) large

Regarding the sectors of the companies:

( ) Metal-mechanic ( ) electronics ( ) Financial / Accounting
( ) Furniture ( ) health ( ) Administrative
( ) Chemical ( ) services ( ) Other______________

Term of Acceptance

The purpose and details of this study were explained.
I understand that this study was designed to deepen knowledge about the aforementioned PSS topic for thesis research.
I had the opportunity to ask questions about my participation.
I understand that I am not obliged to participate in the study.
I understand that all information I provide will be treated as confidential and my name, image and voice will never be disclosed.
I agree to participate in this study.

____
Signature of participant

Appendix I - Discussion Guide of the Focus Group 1

Part 1:

1. **Introduce the researcher/moderator**
2. **Welcome and thank participants for their attendance**
3. **Reinforce why participants were chosen and importance of their contribution**
   The PSS is a latent theme in academia around the world and especially in Brazil there are few research groups on this field. For these reasons the experience of each of you in PSS field is very important for this research and for the advancement of this business model in Brazil and in the world…
4. **Briefly outline how information will be used and by whom**
   The results of this Focus Group 1 will be used as a source of information for the proposition of an eco-innovation-oriented method to support SPSS design proposals for manufacturing SMEs. In this Focus group will be discussed the steps, tasks, tools of PSS for SMEs. The part 2 of the method will realized in the Focus Group 2 in which will be include the eco-innovation tools and perspective.
5. **The purpose of the research should be given in general terms, without revealing the central research questions or hypothesis, as this may pre-empt the direction of the discussion**
   The objective of this GF is, from the perspective of specialists, to define the appropriate stages, tasks and tools for the life cycle of the PSS (BOL, MOL, EOL) adapted to the manufacturing SMEs.
6. **Any specific terminology should also be clarified to provide a common knowledge base for all participants**
   A document content terminology and definitions for this focus group was providing previously to participants (Appendix A).
7. **Explain the purpose of tape recording and seek permission**
   The recording is indicated to facilitate the identification of the specialists x given answers (see Appendix D).
8. **Ensure the confidentiality to the participants**
   All the data are confidential. The identification in the research will be coded by E1, E2, etc (Appendix H).
9. **Indicate the expected duration of the discussion**
   1h30min.
10. **Explain the ‘guidelines’ for conduct of the group discussion**
    - Participants should be told that they do not need to speak in any particular order. However, they need to ensure that only one person speaks at a time to ensure a clear tape-recording.
    - It should be stated that there are no right or wrong answers to the discussion questions and it is the views of each participant which are sought.
    - The moderator needs to reinforce that they are interested in a range of views on each topic, so it is acceptable to disagree with others in the group if they have a different opinion.
    - The moderator should emphasise that their role is to facilitate the discussion, and they are not an expert on the issues of discussion

- Participants should be told to share their comments with the whole group rather than the person seated next to them
- The moderator needs to state that they are most interested to hear participants' own views and opinions and encourage participants to say what they really feel about each of the discussion topics.
- The write answers of each person must been given in the correspondent formulary. This will help the codifying and transcription process and minimize the effect when not all answers the questions.

Part 2:

1. Opening questions

I would ask each participant to introduce themselves and talk a little about their academic experiences in PSS and their insights on the importance of PSSs.

2. Introductory and probing questions

Considering the context of SMEs...

In which aspects the design of PSS models in SMEs differ in comparison to large companies?

In which aspects the design of PSS models in SMEs is similar in comparison to large firms?

What are the key determinants aspects of success in the design and implementation of PSS in SMEs?

3. Transition questions

The literature review of Cavallieri and Pezzotta (2012), based on Service Engineering, presented a synthesis of PSS design models and methods, as well as their stages and tasks contained in each step. However, it did not discuss the segment and size of companies to which they apply (whether large companies, small or medium size). So this contingency specific to the case of manufacturing-based SMEs needs to be done. Moreover, there is not still in the literature a model or even a reference method accepted for PSS design (either for large or SMEs).

4. Key questions

Previous Guidelines to answer the Key questions:

- The information gained from the key questions will be analysed in the greatest depth.
- The key questions may be a series of individual questions or two to three topic areas each containing a series of questions.
- It is during the key questions that the moderator will use the greatest amount of probing to elicit depth and detail in the discussion.
- The most discussion time should be spent on the key questions; in some instances, ten to fifteen minutes may be taken with certain issues or

questions to ensure the issues are fully explored and all participants have had an opportunity to highlight their views.

- Approximately half of the group discussion time is usually taken up in discussing the key questions.

The Key questions:

Considering the phases during the life cycle of PSS design in SMEs (Appendix D, Form 1):

Are these the necessary phases along the life cycle of PSS design to SMEs context? Some phase may be included, excluded or modified in order to successful support the PSS design in SMEs context?

Considering the previous consensus of phases and the activities/tasks during the life cycle of PSS design in Cavalieri and Pezzotta (2012) (Appendix D, Form 2):

Which activities and tasks must be included and performed within each phase to successful support the PSS design in SMEs context?

Considering the consensus of phases and considering the consensus of phases and activities and tasks:

Which engineering or management tools are more suitable to support and realize each activity or task or even a set of activities/tasks to successful support the PSS design to SMEs context?

Considering the SMEs context and also which:

- the Service Engineering require designing business architectures in which networks of customers, suppliers and alliance partners maintain consistent levels of quality, while allowing for minor variances in ends and means.
- the focus in service development is to create prerequisites for long-term profitable customer relations and to attract and keep customers who are satisfied and loyal along the different life cycle phases.
- the main actors or internal and external stakeholders involved in a PSS are: Customer/End-User, Channel, Society and Environment.
- the importance of involving customers and users as co-designers and part of the service results along the PSS life cycle.

  What are the mains interactions between “actors x phases” aiming improve the value addition to customer?

  What are the mains input and output tangible (e.g. product) or intangible (e.g information flow) between the actors and phases aiming improve the value addition to customer?

5. Ending questions

Considering the previous discussion and the individual responses on phases, tasks, tools and interactions in the design of PSS to SMEs:

I would like ask each participant to highlight the key/critical phases, tasks, tools and interactions to consider in PSS design in SMEs.

6. Summary questions

In this stage the moderator summarizes the results of Focus Group and asks to the participants if this summary is appropriate.

7. Final question

In this stage the moderator ask to the participants if something has been forgotten and if the participants have any advice or suggestion for the continuity of the research.

Appendix J

Discussion Guide of the Focus Group 2

Part 1:

11. **Introduce the researcher/moderator**
12. **Welcome and thank participants for their attendance**
13. **Reinforce why participants were chosen and importance of their contribution**
    The PSS is a latent theme in academy around the world and especially in Brazil there are few research groups on this field. For these reasons the experience of each of you in PSS field is very important for this research and for the advancement of this business model in Brazil and in the world…
14. **Briefly outline how information will be used and by whom**
    The results of this Focus Group 2 will be used as a source of information for the proposition of an eco-innovation-oriented method to support SPSS design proposals for manufacturing SMEs.
15. **The purpose of the research should be given in general terms, without revealing the central research questions or hypothesis, as this may pre-empt the direction of the discussion**
    In this Focus group will be discussed strategies and tactics to increase potential of eco-innovation and sustainable value proposition in PSS offers in SMEs.
16. **Any specific terminology should also be clarified to provide a common knowledge base for all participants**
    A document content terminology and definitions for this focus group was provide previously to participants (Appendix B).
17. **Explain the purpose of tape recording and seek permission**
    The recording is indicated to facilitate the identification of the specialists x given answers (Appendix E).
18. **Ensure the confidentiality to the participants**
    All the data are confidential. The identification in the research will be coded by E1, E2, etc (Appendix H).
19. **Indicate the expected duration of the discussion**
    1h30min.
20. **Explain the ‘guidelines’ for conduct of the group discussion**
    - Participants should be told that they do not need to speak in any particular order. However, they need to ensure that only one person speaks at a time to ensure a clear tape-recording.
    - It should be stated that there are no right or wrong answers to the discussion questions and it is the views of each participant which are sought.
    - The moderator needs to reinforce that they are interested in a range of views on each topic, so it is acceptable to disagree with others in the group if they have a different opinion.
    - The moderator should emphasise that their role is to facilitate the discussion, and they are not an expert on the issues of discussion
    - Participants should be told to share their comments with the whole group rather than the person seated next to them

- The moderator needs to state that they are most interested to hear participants' own views and opinions and encourage participants to say what they really feel about each of the discussion topics.
- The write answers of each person must been given in the correspondent formulary. This will help the codifying and transcription process and minimize the effect when not all answers the questions.

Part 2:

1. Opening questions

What are the critical factors that the SME should consider to capture Sustainable VU (economic, environmental and social) and add value to the customers considering the actors and stakeholders involved in the PSS business model?

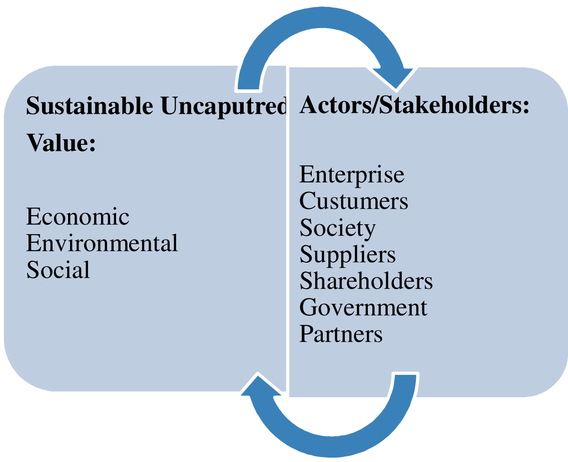

Fig.1. Interaction flow to capture Sustainable VU.

2. Introductory and probing questions

Which actions and strategies should SMEs must take to increase the Value Proposition (economic, environmental and social) in their PSS design? What are the supporting tools for successful realize this task?

In what stages of the PSS life cycle (BOL, MOL or EOL) there are greater potential to generate and leverage Sustainable VU (economic, environmental and social) in manufacturing SMEs? What are the possible actions for this?

3. Transition questions

Generate and leverage Sustainable VU (economic, environmental and social) is a challenge for companies of any size and sector. There is not yet an accepted reference model in the literature to accomplish this task. So, what are the sources and opportunities to generate and leverage VU in the steps and tasks that are part of the PSS life cycle (BOL, MOL and EOL) in manufacturing SMEs?

4. Key questions

Previous Guidelines to answer the Key questions:

- The information gained from the key questions will be analysed in the greatest depth.
- The key questions may be a series of individual questions or two to three topic areas each containing a series of questions.
- It is during the key questions that the moderator will use the greatest amount of probing to elicit depth and detail in the discussion.
- The most discussion time should be spent on the key questions; in some instances, ten to fifteen minutes may be taken with certain issues or questions to ensure the issues are fully explored and all participants have had an opportunity to highlight their views.
- Approximately half of the group discussion time is usually taken up in discussing the key questions.

The Key questions:

- Considering the main responsive and agile sources of Sustainable VU (economic, environmental and social) through the PSS life cycle in SMEs, what other categories of sources can be added at each stage? (Appendix E, Form 1)
- Considering the main responsive and agile aspects of the sources of Sustainable VU (economic, environmental and social) through the PSS life cycle in SMEs, what other aspects can be added at each stage? (Appendix E, Form 2)
- Considering the activities during the PSS life cycle in SMEs, what new responsive/agile activities of Sustainable VU (economic, environmental and social) can occur in the context of SMEs? (Appendix E, Form 3).
- Considering the activities during the PSS life cycle in SMEs, which Engineering or Management tools are most appropriate to leverage the value addition (economic, environmental and social) and unlock the Sustainable VU in an agile/responsive way? (Appendix E, Form 3).

5. Ending questions

What are the critical (maximum 3) sources of Sustainable VU and tools can help SMEs to increase the value addition?

6. Summary questions

In this stage the moderator summarizes the results of Focus Group and asks to the participants if this summary is appropriate.

7. Final question

In this stage the moderator ask to the participants if something has been forgotten and if the participants have any advice or suggestion for the continuity of the research.

CAPÍTULO VII

9 CONCLUSION

9.1 Synthesis of results

The purpose of this thesis was to develop a reference method eco-innovation-oriented to support proposals of sustainable product-service systems for SMEs. To achieve this goal, several specific objectives were defined, such as for example, (i) identify the key determinants and causal relationship between the determinants of eco-innovation in SMEs, (ii) understand the state of the art, elements and challenges related to the transition to product-service systems and sustainable product-service systems, understand the state of the art and key factors involving the transition process to sustainable product-service systems in SMEs, (iii) analyse the potential of systematic innovation methods to generate eco-innovations in the design of sustainable product-service systems; (iv) identify systematic tools and methods for generating eco-innovation in sustainable product-service systems in small and medium-sized manufacturing enterprises; (v) develop an eco-innovation-oriented reference method to support sustainable product-service system proposals in manufacturing SMEs, evaluating the proposed method and propose improvements. The final results permitted pointed that all intermediary targets were achieved and mainly the reference method was proposed.

9.2 Propositions, concepts and tools created or extending as result of research

- A systemic modelling relationship among the determinants for eco-innovation in manufacturing SMEs was elaborated (Chapter 2).
- Was confirmed the hypotheses that PSS and SPSS might be considerate distinct, although no totally independent disciplines. On one hand, PSS are more focused in business dominant-logic, customer needs and system perspective of product-service oriented offers. On the other hand, SPSS concept is based on eco-efficiency and in a TBL perspective, carrying the potential to deliver social well-being and economic prosperity while operating within the limits of our planet enabling a Circular Economy (Chapter 3).

- In chapter 4, an innovative Matrix supporting the decision making process by SMEs along the transition process to SPSS was proposed and incorporated in the method. Also, two corollaries emerged:
  Corollary 1: The transition process towards SPSS must be done incrementally instead radically.
  Corollary 2: The engagement of manufacturing SMEs in partnership and networks to develop the SPSS offers has potential to minimize the competence gaps and enable more innovative, complete and competitive value proposition to customers.
- A new concept was proposed in chapter 5 extending the study by Yang et al. (2017):
  "Sustainable Value Uncaptured is the set of economic, social and environmental benefits that could be captured but have not yet been captured by the enterprise and may be incorporate in a new or in a existent SPSS offer".
- New sources and new detailed aspects of Sustainable VU were proposed extending the results initially proposed by Yang et al. (2017) resulting in a relevant theoretical contribution in chapter 5.
- A category of source to new value proposition to EOL named "New value proposition to EOL products" and the respective new detailed aspects of Sustainable VU emerged as insight during the research, extending the study by Yang et al. (2017).

completar

9.3 Research gaps filled

Several research gaps pointed by literature were filled with the results of this study. For example, previous researches published in the leader journal on eco-innovation, the *Journal of Cleaner Production,* are focused on different topics on eco-innovation in SME (Cai and Zhou, 2014; Klewitz and Hansen, 2014; Cuerva et al., 2014) and do not address specifically the proposition of a method integrating the PSS business models. In this sense, this research proposed a reference method filling this research gap.

The literature also suggested the need of to explore the potential synergies among SPSS and other promising and interwoven sustainability concepts (Vezzoli et al., 2015). In the case this reference method discusses the synergy with the eco-innovation concept. Moreover, the most part of literature focus mainly on large and often multinational companies, overlooking the significant contribution from SMEs. In the same way, the existing background of literature for SPSS transition in SMEs are fragmented and insufficient to support a fluid transition process. Although studies demonstrated the potential of TRIZ in different topics on sustainability and cleaner production, none study is focused specifically on the transition towards SPSS business models. In this perspective, this study makes a theoretical contribution to the SPSS field integrating these previous approaches.

Finally, for some decades PSS have been known and acknowledged as effective means towards more sustainable production and despite of several singular initiatives, PSSs have still not been implemented widely. The possiible reasons for this failure to disseminate the concept are related with the lack of inappropriate supporting methods and tools (Annarelli et al., 2016; Ceschin, 2014; Cavalieri and Pezzotta, 2012; Tukker and Tischner, 2006). In this sense, this study addresses these previous research lacks making an effective contribution to practical and theoretical perspective.

9.4 Limitations and further research

On the whole, the expected results of this research were achieved and a reference method eco-innovation-oriented to support proposals of sustainable product-service systems for SMEs was developed. This research has limitation that must be considered. Beyond the limitation stated in the end of each paper, a general and possible limitation of this study resides in the fact that the reference method was not tested in a real SME. In this sense, is indicated that successive cycles of applications of the reference method be conducted aiming improve the method from its current stage.