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

RENATO LEWENTHAL CARRIÃO

Método de representação de soluções de internet das coisas (IoT)
durante o design de um modelo de negócios de um Sistema
produto-serviço (PSS)

Method to represent IoT solutions during the Business Model Design of a
Product-Service System (PSS)

São Carlos
2018

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Method to represent IoT solutions during the Business Model Design of a
Product-Service System (PSS)

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

Concentration Area: Processes and
Operations Management

Supervisor: Prof. Dr. Henrique Rozenfeld

São Carlos

2018

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C316m Carrião, Renato Lewenthal
 Method to represent IoT solutions during the business
 model design of a product-service system (PSS) / Renato
 Lewenthal Carrião ; Thesis directed by Henrique
 Rozenfeld. -- São Carlos, 2018.

 Master (Thesis) Graduate Program in Production
 Engineering and Research Area in Process and Operations
 Management - São Carlos School of Engineering, at
 University of São Paulo, 2018.

 1. Product-service system. 2. Internet of things
 representation. 3. Business model design. 4. Business
 model Innovation. I. Title.

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

Área de Concentração: Processos e Gestão de Operações

Orientador: Prof. Dr. Henrique Rozenfeld

São Carlos

2018

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Ficha catalográfica elaborada pela Biblioteca Prof. Dr. Sérgio Rodrigues
Fontes da EESC/USP

C316m	<p>Carrião, Renato Lewenthal</p> <p>Método de representação de soluções de internet das coisas (IoT) durante o design de um modelo de negócios de um sistema produto-serviço (PSS) / Renato Lewenthal Carrião ; orientador Henrique Rozenfeld. -- São Carlos, 2018.</p> <p>Dissertação (Mestrado) - Programa de Pós-Graduação em Engenharia de Produção e Área de Concentração em Processos e Gestão de Operações -- Escola de Engenharia de São Carlos da Universidade de São Paulo, 2018.</p> <p>1. Sistema produto-serviço. 2. Representação de internet das coisas. 3. Desenho do modelo de negócios. 4. Inovação do modelo de negócios. I. Título.</p>
-------	---

Elaborado por Elena Luzia Palloni – CRB 4464

FOLHA DE JULGAMENTO

Candidato: Engenheiro **RENATO LEWENTHAL CARRIÃO**.

Título da dissertação: "Método de representação de soluções de internet das coisas (IoT) durante o desing de um modelo de negócios de um sistema produto-serviço (PSS)".

Data da defesa: 28/09/2018.

Comissão Julgadora:

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ACKNOWLEDGEMENTS

First of all, I would like to thank Professor Henrique Rozenfeld for the outstanding supervision, which comprised his profound knowledge in the subject of my research and his excellence in teaching and researching. Furthermore, while considering that I was in the market for so many years, Professor Rozenfeld was very generous and patient along the development of my research. Without his knowledge, experience, and generosity it would not be possible for me to achieve the results.

Moreover, I would like to thank Professor Eduardo de Senzi Zancul and Professor Fredy João Valente, for the discussions and orientations given during my qualification exam, which supported me on making a profound change in the objectives of my research.

I would like to sincerely thanks my colleagues from the Integrated Engineering Research Group, especially those who were directly involved during all this period providing important insights, to the proposition of the “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)”. Maiara Rosa, Sania da Costa Fernandes, and Carolina Queiroz, thank you very much for your contributions that enriched this study.

In addition, I would like to thank all colleagues that participated in the initial evaluation of the proposed method, during the focus group meeting. Their contributions were very important to indicate potential improvements to the method, as well as directions for future research.

I am also very grateful to my wife Ana Patrícia Carrião, who gave me full support with love and care, which were really fundamental for me during the development of my entire work. I am also grateful to my parents, who still by my side after so many years making me blessed for that.

Finally, I would like to acknowledge FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo), for the *PSS Transition Framework* research project in which this study was comprised.

ABSTRACT

CARRIAO, R. L. **Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)**. 2018. Dissertação (mestrado) – Escola de Engenharia de São Carlos, São Carlos, 2018.

Considering the competitiveness of global markets within an ever-changing environment, a company's Business Model should be able to innovate constantly to capture value within the company, while addressing better the customer needs. The PSS Business Model represents an innovation while providing value to the customer supported by a combination of products and services. However, the PSS Business Model also needs to innovate constantly. The Internet of Things (IoT) comprises networked objects able to interact with each other and to people, to reach common goals with a high level of efficiency, thus presenting potential to create a new value proposition to PSS Business Model Design. However, the existing literature represents an IoT solution into PSS Design, using either technical constructs or a high level free textual description. The goal of this study is to propose a "Method to support the representation of IoT solutions during the PSS Business Model Design". The method was developed based on the Design Research Methodology (DRM), comprising three research stages. During the first and second stages, a literature review was conducted to generate theoretical requirements for guiding the proposition of the method. During the third stage, the requirements were developed, and multiple case studies using secondary sources were used to propose the method in theory. During the final activity of the third stage, an exploratory application of the method for a Driverless PSS Car Sharing were applied and its results, as well as all the method's artifacts, were object of an initial evaluation by a focus group. The results indicated that method has potential to provide a common language for the PSS Business Model designers, while providing detailed information, to be added to the dimensions of a PSS Business Model that comprises IoT solutions.

Keywords: Product-service system. Internet of things representation. Business model design. Business model innovation.

RESUMO

CARRIAO, R. L. **Método de representação de soluções de internet das coisas (IoT) durante o design de um modelo de negócios de um Sistema produto-serviço (PSS)**. 2018. Dissertação (mestrado) – Escola de Engenharia de São Carlos, São Carlos, 2018.

Considerando a competitividade dos mercados globais dentro de um ambiente de constante mudança, o modelo de negócio de uma empresa deve ser capaz de inovar constantemente, capturando valor dentro da empresa ao mesmo tempo em que atende melhor as necessidades dos clientes. O modelo de negócio de PSS representa uma inovação ao entregar valor ao cliente através de uma combinação de produtos e serviços. No entanto, o modelo de negócio de PSS também precisa inovar constantemente. A Internet das coisas (IoT) compreende objetos em rede capazes de interagir uns com os outros e com as pessoas, para alcançar metas comuns com elevado nível de eficiência. Dessa forma, apresenta potencial para criar a nova proposta de valor para o desenho de modelo de negócio de PSS. No entanto, a literatura existente representa a solução de IoT usando ou constructos técnicos, ou um nível alto de descrição textual. O objetivo deste estudo é propor um “Método de representação de soluções de internet das coisas (IoT) durante o design de um modelo de negócios de um Sistema produto-serviço (PSS)”. O método foi desenvolvido com apoio da “Design Research Methodology” (DRM), sendo composto de três fases de investigação. Durante a primeira e a segunda fase, realizou-se uma revisão da literatura para gerar requisitos teóricos para orientar a proposição de método. Durante a terceira fase, foram desenvolvidos requerimentos e analisados múltiplos estudos de caso, usando fontes secundárias, para propor o método na teoria. Durante a atividade final da terceira fase foi realizada uma aplicação exploratória do método, em um caso de um PSS de “uso compartilhado de carros” usando um carro autônomo. Em seguida todos os artefatos do método, e os resultados dessa aplicação exploratória, foram objeto de uma avaliação inicial por um grupo focal. Os resultados indicaram que o método tem potencial para fornecer uma linguagem comum para os desenvolvedores de modelo de negócio de PSS, proporcionando informações detalhadas, a serem adicionadas às dimensões de um modelo de negócio de PSS.

Palavras chaves: Sistema produto-serviço. Representação de internet das coisas. Desenho do modelo de negócios. Inovação do modelo de negócios.

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LIST OF ABBREVIATIONS

BMD	Business Model Design
BMC	Business Model Canvas
BPML	Business Process Modeling Language
CPS	Cyber-Physical Systems
DRM	Design Research Methodology
DT	Design Thinking
EI	Grupo de Engenharia Integrada (Integrated Engineering Group)
eEPC	Extended version of the Event-driven Process Chain
FMEA	Failure Mode and Effects Analysis
ICT	Information and Communication Technology
IoT	Internet of Things
IPPS2	Industrial Product-Service Systems
ITU	International Telecommunications Union
MC	Mobile Computing
NFC	American National Science Foundation
SOA	Service Oriented Architecture
PaaS	Product as a Service
PC	Pervasive Computing
PSS	Product-Service System
WSN	Wireless Sensor Networks
XML	Extensible Markup Language

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1 Introduction

This chapter is organized into three sections. The first section (section 1.1) aims to introduce the main themes covered in this research and to justify this work in the literature's context. The second section (section 1.2) defines the research's question and objective. Finally, the third section (section 1.3) presents the structure of this document to support the reader in understanding this work.

1.1 Context and justification

Global markets and technologies have evolved fast in the last ten years, thus increasing market competitiveness and making more difficult for a company to differentiate its strategy. While companies may have extensive investments to develop new products and technologies, the commercialization of any new offering will rely on their business models (CHESBROUGH, 2010, p. 354). This new environment also encompasses the necessity to address better the customer needs while being able to "capture value from providing new products and services" (TEECE, 2010, p. 172).

The Business Model comprises "the means by which a firm creates and sustains margins or growth" (EUCHNER; GANGULY, 2014, p. 33). However, while considering an ever-changing market environment, the innovation on Business Model Design is as important as product innovation to differentiate the firm's strategy and make it hard to be replicated by competition (TEECE, 2010, p. 173)

Tan (2010, p. 174) stated that PSS seems to address four possibilities for innovation, such as product innovation, process innovation, position innovation regarding the ways a product or a service are introduced to the customers, and paradigm innovation regarding profound changes on what the organization does.

The PSS concept can be understood as a system of products, services, actors' network and infrastructure that deliver value to the final customer through its use, without transferring the product ownership. Therefore, also presenting potential to have a lower environmental impact (BAINES et al., 2007; MONT, 2004a)

Nemoto et al. (2015, p. 1279) also state that the PSS design must provide value to the customer during the entire product lifecycle, and Morelli (2003, p. 75) states that a PSS represent a shift to designers that should focus on the use phase, regarding delivering the value proposition to the customer. Therefore, using all these

characteristics, PSS almost often represents a Business Model innovation in regards to the company's traditional Business Model (PIERONI et al., 2016, p. 413; TAN, 2010, p.12; VELAMURI et al., 2013, p.21).

There is a wide range of literature related to PSS produced during the last 20 years, as well as there are several successful implementations of PSS in Industry during that period (BAINES et al., 2007, p. 1548; MONT, 2004, p. 24-25). However, the total revenue generated by services compared to the total amount of revenue generated by products did not improve since 2007. Moreover, the same result was found even when analyzing the internal data of PSS early adopters companies, such as Rolls Royce (NEELY; BENEDETTINI; VISNJIC, 2011. p. 6), as depicted in Fig. 1. PSS present a huge challenge to any company related to the shift from selling products to provide product-services since the first implementation. On the other hand, once created the new Business Model, it must evolve to differentiate the company from competition (EUCHNER; GANGULY, 2014, p. 33).

Figure 1 – Percentage of revenue that resulted from services while compared to revenue that resulted from products

SOURCE: Neely, Benedettini and Visnjic (2011, p. 7)

Vasanth et al. (2012, p.3) in a comprehensive review regarding the state of art methodologies for PSS design stated that “in servitization, product-service systems (PSS) form a special case”, and that the industries require tools, techniques, and

methods to support the transformation of a company's business strategy towards PSS.

The Internet of Things (IoT) can create value to offerings based on the aggregation of its objects abilities of intelligence, awareness, and interaction (KORTUEM et al., 2010, p. 30). Moreover, the evolution of both sensing enabling technology and associated processing will result in "systems-of-systems that synergistically interact to form new, unpredictable services" (STANKOVIC, 2014, p. 1).

The "smart products" that comprise IoT's objects may be understood as a complex bundle of sensors, communication devices, IT hardware and both local and "cloud" based software applications (PORTER; HEPPELMANN, 2014, p. 5). Furthermore, the previous authors emphasized that to leverage the full potential of this complex bundle of technologies, "the system that connects products will be the core advantage, not the products themselves" (PORTER; HEPPELMANN, 2014, p. 14).

Bucherer and Uckelmann (2011, p. 258, 259) stated that business model innovation results in a qualitatively new Business Model, and that new Business Models based on IoT almost often change or even replace traditional Business approaches. Moreover, the previous authors stated that IoT represents an important enabler to PaaS (Product as a Service) scenarios, which present the same characteristics of PSS scenarios, as described by Bucherer and Uckelman (2011, p 266).

The synergy between IoT connected products and PSS Business Models is also emphasized by Porter and Heppelmann (2014, p. 11) while stating the "new business models enabled by smart; connected products can create a substitute for product ownership."

Dijkman et al. (2015, p. 676), identified relevant types related to IoT applications for each Business Model Canvas' building block, with emphasis on the value proposition, key partnerships, and customer relationship building blocks. It is important to notice that other references named the Business Model's building blocks as "Business Model's dimensions," and that these two ways to name it to represent the same meaning for this research. The most important identified building blocks and its types for IoT offerings are depicted in Figure 2, where the gray area indicates the results from the interviews with 11 IoT related IoT offering companies, and the

other types were classified by the degree of significance that resulted from a survey with 300 responses, and 72 analyzed cases

It is also important to notice that, as depicted in Figure 2, the most important Revenue Streams types identified by both the interviews and the survey, can be related to PSS such as lending/renting/ leasing, licensing, subscription fees, and usage fees. However, a literature survey performed by the previous authors showed that “the research area of IoT business models is relatively unexplored” (DIJKMAN et al., 2015, p. 673).

Figure 2 – Business Model Framework for IoT with most important types (#<0.05 significance, *<0.02 significance, **<0.01 significance). The marked types were added by users during the development of this analysis

Key Partners Software developers ** Launching customers ** Data interpretation ** Hardware producers * Service partners Distributors ** Other suppliers ** Logistics **	Key Activities Product development ** Software development Customer development Service; Implementation Platform development Sales; Marketing Partner management ** Logistics ** Key Resources Software ** Employee capabilities # Relations Physical resources Intellectual property Financial resources *	Value Propositions Convenience/usability ** „Getting the job done“ ** Performance ** Possibility for updates * Comfort # Accessibility Cost reduction Risk reduction Customization Design Price ** Newness ** Brand/status **	Customer Relationships Communities ** Co-creation * Self-service Automated service Personal assistance Dedicated assistance ** Channels Web sales ** Partner stores Sales force Wholesaler Own stores **	Customer Segments Multi-sided platforms Mass market Diversified Niche market Segmented
Cost Structure Product development cost ** IT cost Hardware/production cost Personnel cost Marketing & sales cost Logistics cost **			Revenue Streams Subscription fees ** Usage fee ** Asset sale # Lending/renting/leasing Licensing Advertising Startup fees * Installation fees * Brokerage fees **	

SOURCE: Dijkman et al., (2015, p.675, 676)

This present research was developed in the context of the methodology proposed by the “PSS Transition Framework” described by Pieroni et al. (2016, p. 413). In this framework after evaluating the current business and defining new challenges, it begins the PSS design based on the traditional representation of a new Business Model. The authors considered this version as an “initial Business Model” that is useful, but “lack the appropriate level of detail” (PIERONI et al., 2016, p. 413). Therefore they proposed a business process architecture, which represents a detail of the “activity” dimension of the Business Model CANVAS, and connects partners and internal organizational elements to the processes as well the resources required

to support the processes (OSTERWALDER; PIGNEUR, 2010, p. 37; PIERONI et al., 2016, p. 415). This architecture is an intermediate level between the business model and the detailed design. The hypothesis is that such representation fills up the gap between the abstraction level of the business model and the detailed design so that the further steps of the PSS design can rely on the architecture. This research considers the same hypothesis concerning the application of IoT as an enabler to the PSS.

The level of description of the most important building blocks and types proposed by Dijkman et al. (2015, p. 676) is appropriate for an initial Business Model version. However, this level does not comply with the “PSS Transition Framework” in which the context of this research is inserted.

Furthermore, the representation of specific IoT objects found in the literature were almost often based on either a free textual description or in a very technical approach, (ATZORI; IERA; MORABITO, 2010; PORTER; HEPPELMANN, 2014; RYMASZEWSKA; HELO; GUNASEKARAN, 2017; SHIH; LEE; HUARNING, 2016; ZANCUL et al., 2016). The existing proposals do not provide detailed information regarding the specification of IoT during the Business Model Design that could be used in the “PSS Transition Framework” related to a complex bundle of products, services, and systems that comprise “smart products”.

1.2 Research question, and objective

The research justification described in section 1 leads to the following research question: How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”?

To answer the research question, the objective of this study is to propose a “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)”. The method aims to detail IoT main functions to support the PSS value proposition, using a specific IoT object representation.

1.3 Document structure

This document is structured in five chapters, as depicted in Figure 3.

Chapter 1 introduces the content of this work and presents the context and justification, the research problem, question and objective, and the document structure.

Chapter 2 contains a literature review of the main themes approached by this work, as well as the considerations that will guide the research's artifacts design and development.

Chapter 3 describes the methodology applied in this research. It is divided into two sections that encompass the methodological approach

Chapter 4 attempts to presents the research results as well as the discussion regarding both the theoretical background and the findings from the empirical studies that were developed in the field.

Chapter 5 presents the conclusions of this research, limitations, and future research opportunities.

The appendix A is described in section 3.2.3.2

Figure 3 – Document Structure

SOURCE: Created by the Author

2 Literature review

This chapter presents the theoretical background that supports the design of the Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS) proposed in this research. It is a deliverable ((D.1) *Literature Review*) of DS-I stage of this research, as described in section 3.2.2.

2.1 Product-Service Systems (PSS)

The first definition of a Product-Service System (PSS) was introduced 18 years ago by Goedkoop et al. (1999, p. 17), as a combination of products, activities that are done for others with an economic value representing the services, and a collection of elements and relations representing the system. Since then, a comprehensive theoretical knowledge has been developed.

Tukker (2004, p. 248) defined a still well-accepted PSS typology, with three main categories:

- Product-oriented, where physical product ownership is transferred to the customer and a bundle of services is added to the offer;
- Use-oriented, where the physical product functionality usage represents a major role on the PSS value creation, but the product ownership is not transferred to the customer;
- Result-oriented services, where the PSS value is represented by its final result, regardless of which product is part of the offering.

Therefore, while using a PSS Business Model a combination of products and services are systemized to fulfill the customer needs during the whole offering's life cycle, instead of transferring the product ownership (BAINES et al., 2007b, p. 1547; MANZINI; VEZZOLI, 2003, p. 851). Boehm and Thomas (2013, p. 252), performed a comprehensive literature review of PSS concepts and definitions with 265 articles, which corroborate that PSS offering is focused on "creating customer utility and generating value" supported by activities performed during the use phase.

The PSS structure defined by Aurich; Fuchs; Wagenknecht (2006, p. 1481), illustrated some of these concepts as a combination of physical and non-physical components that jointly constitute a physical product core "enhanced and individualized by a mainly non-physical shell," as depicted in Figure 4. Thus,

providing the customer with “life cycle oriented benefits” (AURICH; FUCHS; WAGENKNECHT, 2006, p. 1481).

Figure 4 – PSS Structure

SOURCE: Aurich, Fuchs and Wagenknecht (2006, p.1481)

While the product-service functionalities may support the core benefits delivered to the customer other PSS aspects must be considered important as well. Likewise, Morelli (2003, p. 75, 98) stated that the design of a PSS should also emphasize other key elements. Elements such as the analysis of the cultural, technical and social aspects that generated the PSS concept; the analysis of social and cultural requirements of stakeholders, as well as their usage patterns; the proposition of new values and its translation into concrete design actions. Meier et al. (2010, p. 622) also discussed other important issues regarding the PSS life cycle, such as the integration needed between different providers of products and services; the strong integration of customers; and the management of processes of value-added, quality management, customer feedback, as well as decision-making.

A comprehensive study based on a useable sample of more than 10.800 firms was performed by Neely et al. (2011, p. 6). One important result of this study showed that from 2007 to 2011 the firms classified as servitized, grew from 29,52% to just 30,10%. Even considering that the total amount of firms considered in the study's

sample grew by 30% and that it could mean that the total amount of servitized firms grew similarly, the data indicated that there wasn't a significant percentage shift to services in the period. Regardless the PSS potential to better address the customer needs; there are barriers for the PSS Business Model adoption related to the cost necessary to provide services that require a more labor-intensive based Business Model, as well as different skills within the companies (TUKKER, 2015, p. 88).

Therefore, it is important to understand how all the actors involved in PSS activities interact to provide new value to the final customer and to support an innovation strategy able to overcome the existing barriers to growth (NEELY; BENEDETTINI; VISNJIC, 2011, p. 6; TAN, 2010, p. 12, 168).

2.2 Application of IoT in PSS

2.2.1 *Internet of Things (IoT)*

A widely accepted definition for the Internet of Things (IoT) concept was proposed by Atzori et al. (2010, p. 2787), as a variety of things or objects that “can interact with each other and cooperate with their neighbors to reach common goals.” The Telecommunication Standardization Sector of ITU-International Telecommunications Union (2012, p. 2), also describes the IoT as an infrastructure of interconnected things (physical and virtual), based on “existing and evolving interoperable information and communication technologies,” which enables new advanced services. Another well-accepted definition is that the Internet of Things (IoT) can be represented by an infrastructure of networked objects, which comprises autonomous physical/digital objects augmented with sensing, processing, and network capabilities (KORTUEM et al., 2010, p. 30).

However, it is important to notice that other research communities are researching the “smart world” of mobile phones, cars, industries, cities and so on. Stankovic (2014, p.1), listed at least five relevant research communities dealing with similar concepts: Internet of Things (IoT); Mobile Computing (MC); Pervasive Computing (PC); Wireless Sensor Networks (WSN); and Cyber-Physical Systems (CPS), which is related to the study of Industry 4.0.

On the other hand, there are many similar concepts shared by these different research communities. Jazdi (2014, p. 1), discussed that the “dawn of the fourth Industrial Revolution” was a result of the connection of CPSs (Cyber-physical

systems), understood as embedded systems able to generate and exchange information over a network, with the Internet, thus configuring an “Internet of Things.” Gubbi et al. (2013, p. 1645), proposed that IoT concept “need to go beyond the mobile computing (MC) scenario of smartphones and portable devices, to interconnect existing everyday objects and embedded intelligence into a new environment.” Miorandi et al. (2012, p. 1511) described an American National Science Foundation (NSF) Cyber-Physical Systems Program launched in 2008, as an IoT related project.

Therefore, it is possible to identify an increasing overlap of principles and research questions, which are based on the same research focus on enabling technologies, such as real-time computing, machine learning, security, signal processing, big data and other (ATZORI; IERA; MORABITO, 2010, 2789, Fig 1; JAZDI, 2014, p. 1; MIORANDI et al., 2012, p. 1498; TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU, 2012, p. 2; STANKOVIC, 2014, p. 1). Thus, this research will refer to this group of principles as “IoT.”

The technology is deploying a sort of sensors not only equipped with the usual capabilities but also with new potentials, such as autonomous and proactive behavior, context awareness, collaborative communications and elaboration (ATZORI; IERA; MORABITO, 2010, p. 2789). These capabilities can support a virtual cycle of value improvement, as described by Porter and Heppelmann (2014, p. 5).

Gubbi et al. (2013, p. 1651) proposed a bold “object-centric architecture,” where the smart object represents the core concept and can support “plug and play” modular usability, represented by the capability to be deployed in any environment, and interoperate with other smart objects around them. This architecture is focused on ubiquitous cloud-based applications, which can be dynamically shared by different smart products (GUBBI et al., 2013, p. 1654). However, the critical issues related to real-time data processing of large amounts of data, guaranteeing privacy and data management issues represent a challenge for such a platform shortly (GUBBI et al., 2013, p. 1658).

A critical issue regarding the IoT research context is to define “architectures and methods for ‘virtualizing’ objects by creating a standardized representation of smart objects in the digital domain” (MIORANDI et al., 2012, p. 1499). This standard representation of IoT’s objects is important to seamlessly integrate the functionalities

and resources provided by heterogeneous objects, into value-added services for customers

In that sense, Kortuem et al. (2010, p. 31) proposed an IoT's "smart object" model that comprises three design dimensions, which seems to comply with Miorandi et al. (2012, p. 1499) and Atzori et al. (2010, p. 2792), as follow:

- Awareness: represents a smart object's ability to understand the context of events and human activities occurring in the physical world; such as plain activities, domain-specific policies, and work processes.
- Representation: represents the core applications model ability to support activities, such as aggregation of information function model, rules-based model and workflow based model.
- Interaction: represents the smart object's "ability to interact with the user"; such as threshold warnings and context-aware task guidance.

Kortuem et al. (2010, p. 31) applied the proposed smart object model in the industry and found that the most useful designs were not spread throughout the design space, being rather represented by clusters of objects with equivalent dimension levels within that space, as depicted in Figure 5.

Figure 5 – Smart Object Model

SOURCE: Kortuem et al. (2010, p. 31)

2.2.2 IoT applications enabling new value proposition to PSS

The IoT's applications have the potential to add new value proposition scenarios of services and activities, which can be added to a PSS by the objects (things) of the Internet of Things. Atzori et al. (2010, p. 2793), emphasized that the IoT technologies enable several new applications that are not currently available nowadays, based on its objects capability to communicate and “elaborate the information perceived from surroundings.” The previous authors grouped the IoT applications into the domains depicted in Figure 6.

Figure 6 – IoT applications domains and relevant major scenarios

SOURCE: Atzori et al. (2010, p. 2794)

Porter and Heppelmann (2014, p. 4) also highlighted the IoT applications potential of adding new value proposition to the society, using products that “become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in myriad ways.” These systems are disrupting value chains and obligating companies to rethink how they design, manufacture and operate them, as well enabling new business models (PORTER; HEPPELMANN, 2014, p. 5, 11).

Furthermore, within these complex systems the functionality of one product may be optimized with other related products, composing an offering of product-systems and

systems of systems, where the client's product ownership can be substituted by the "performance of the broader product system" (PORTER; HEPPELMANN, 2014, p. 13), or even a system of systems as depicted in Figure 7.

Figure 7 – Product System and System of Systems of Smart Products Offering

SOURCE: Porter and Heppelmann (2014, p. 13)

Leminen et al. (2012, p. 16), described the challenges of IoT's Business Model Design and discussed the links between business models and IoT ecosystems. The authors presented the Daimler AG "Car2Go" car sharing PaaS (product as a Service) concept, as an example of offering that uses IoT to address the customer needs economically and "as environmentally as possible" (LEMENINEN et al., 2012, p. 21). Bucherer and Uckelmann (2011, p. 255) discussed IoT based on the Business Model Concept with focus on the economic perspective and emphasized how important is the process of business model innovation. The PaaS business model prime scenario for IoT was described by the authors as "a major trend in business innovation" while providing services rather than products (BUCHERER; UCKELMANN, 2011, p. 266).

The objects of IoT have abilities to memorize, communicate and deliver services, and are named by Shih, Lee and Huarng (2016, p. 2) as "pseudo actors," because they can support or even replace human actors and affect the design of service-systems. Therefore, the authors proposed a method to help designers to visualize the actor's network of a PSS including the IoT's pseudo actors, to detail the "flow of products,

services and information among them” (SHIH; LEE; HUARNG, 2016, p. 3, 6). The objective of the proposed method was to support the concept selection of IoT solutions, with the following main steps that represent interesting insights for this research:

- “Step 1. Find customers’ unmet needs or dissatisfaction”;
- “Step 2. Identify candidate objects as “pseudo actors” and the potential use of IoT technologies”;
- “Step 3. Analyze whether the identified actors and pseudo actors, along with IoT technology and together with the flows of products, services, and information, could offer solutions to unmet needs”;
- “Step 4. Use a recommended table to summarize “problems” and corresponding feasible solutions”;
- “Step 5. Evaluate the contribution of each alternative combination of IoT technologies to each unmet need”;
- “Step 6. Calculate the total weighted scores and select the optimal alternative”.

The method was applied in a case of “Developing Battery Swapping Services for Electric Scooters in Taiwan,” and the main objective was to find the best alternative concepts related to IoT solutions (SHIH; LEE; HUARNG, 2016, p. 8).

Dijkman et al. (2015, p. 672) work discussed in section 1.1, outlined the “little academic knowledge on how business models for IoT applications differ from business models for other application and how they should be constructed.” The Dijkman et al. (2015, p. 677) discussion regarding the most important building blocks and respective types, depicted in Figure 2, presented useful information for this research, as follow:

- The three building blocks mainly indicated for IoT applications by the interviews were “value proposition,” “customer relationships,” and “key partners.” Nevertheless, the survey pointed out also the “Revenue streams,” “Customer segments,” and “Cost structure” as equal to or above the mean, as depicted in Figure 8.

- The “Value Proposition” building block with its “cost reduction” type was indicated by 7 of the 11 interviews, which reinforce that specific characteristic as expected from IoT applications;
- The “Key Partners” building block with its “service partners” type was indicated by the interviews, as well as full third-party applications suppliers;
- The “Customer Relationship” building block with its “self-service type” was indicated by the interviews, and may represent a culture shift in the organization, as well as the customer, will relate to that organization;
- As discussed in section 1.1 (Context and justification), the survey results highlighted the lending/renting/leasing types for revenue stream building block, which are suitable for PSS offering.

Figure 8 – Relative importance of building blocks (survey)

SOURCE: Dijkman et al. (2015, p. 676)

Rymaszewska et al. (2017, p. 93), analyzed “the process of value creation in servitization through the IoT lens,” within the context where IoT potentially adds opportunities to create value and change the value chain position of a company. The previous authors work analysis was based on the case studies of three B2B manufacturing companies, which evolve from pure product sale of machinery to

services that were gradually evolving enabled by IoT applications (RYMASZEWSKA; HELO; GUNASEKARAN, 2017, p. 99), as described below:

- Company A is a large company manufacturing sheet metal machines;
- Company B is a large multinational company provider of power generators;
- Company C is a large multinational company that produces large power transformers that are used in electricity distribution networks.

To enable a comparative analysis the work choose similar B2B companies with successful IoT based servitization implemented over a three year period. The three companies implemented similar IoT applications focused on control and monitoring capabilities. The criteria used in the analysis to compare the results was adapted from Porter and Heppelmann (2014), which were based on both technological and business strategic issues (RYMASZEWSKA; HELO; GUNASEKARAN, 2017, p. 97), as follow:

- Selecting smart capabilities;
- Embedding functionalities: product and cloud;
- Open vs. closed system;
- Development of capabilities performed in-house or externally;
- Data to be captured, secured, and analyzed;
- Ownership and access rights to product data;
- Full or partial disintermediation of distribution channels/service networks;
- Business model change;
- Entering new markets by monetizing product data by selling it to outside parties;
- Expanding the company's scope.

The results of Rymaszewska et al. (2017, p. 101) showed that “IoT-powered servitization enabled the studied companies to expand the scope of their value creation beyond traditional design and manufacturing” while affecting performance indicators related to solution providers, local operators, and local service personnel. A summary of these results is depicted in Table 1.

Table 1 – Summary of case companies

	Main service functionality	Value proposition measured	IoT functionality	Monetization of service
Company A	Operations support and optimization	Reduced manufacturing costs of a unit, possibility of offer a competitive price	Production and operations data captured for OEM	Product sold as investment Monthly fee
Company B	Maintenance support	Reduced risks of outage, penalty costs	Detailed machine-level sensor data	Part of larger service contract
Company C	Local maintenance support	Increased product lifecycle	Connecting transformer to intranet access	Option in a product, no subscription fee

SOURCE: Rymaszewska et al. (2017, p. 101)

It is important to notice that the results described in Table 1 were obtained by the study of IoT applications with smart capabilities of monitoring and control, described by Porter and Heppelmann (2014, p. 8) study in which Rymaszewska et al. (2017, p. 97) criteria of analysis was based, as depicted in Figure 9.

Therefore, while the results obtained by Rymaszewska et al. (2017) study demonstrate the potential of IoT “monitoring and control smart capabilities” based solutions to enable servitization, the potential of IoT solutions with “Optimization and Autonomy” capabilities should be investigated either.

Figure 9 – Capabilities of Smart, Connected Products

SOURCE: Porter and Heppelmann (2014, p. 8)

ZANCUL et al. (2016, p. 306) also emphasized the opportunity represented by the adoption of IoT within the servitization trend in machinery industry, and proposed a method for “adopting IoT enabled PSS considering business model and product enhancements.” The previous authors proposed method was applied in a real case of a startup that produces solvent and diluent recycling machines. The method comprised both Business Model Design activities to support the company’s PSS strategy, and failure mode and effects analysis (FMEA) to identify what should be monitored in the product (ZANCUL et al., 2016, p. 310), as depicted in Figure 10.

The FMEA application regarding the product resulted in examples of IoT solutions that addressed the most critical modes of failure depicted in Table 2 (ZANCUL et al., 2016, p. 316). The IoT above solutions are related to the monitoring and control capabilities of smart products, described by Porter and Heppelmann (2014, p. 8) and depicted in Figure 9, in the same sense of Rymaszewska et al. (2017) work. The use of FMEA was important to the detail and prioritizes the IoT solutions able to address critical issues, thus adding value to the product and the PSS offering (ZANCUL et al., 2016, p. 320).

Figure 10 – Framework for research design and proposed method

SOURCE: Zancul et al. (2016, p. 310)

Table 2 – Examples of IoT solution options to address the most critical modes of failure

Modes of failure	IoT solution options	Expected result
Temperature or cycle time setting not appropriate for the solvent or diluent to be recycled	Connected n-positions selectors for temperature and cycle time Connected display with selection of parameters	To be able to know the settings and change them remotely
Opening the lid while temperature is still too high	Connected pneumatic actuator with external sensor Connected pneumatic actuator with embedded sensor Connected electrical lock Sensors (hall effect, infrared or limit sensors)	To be able to lock the lid when necessary To be able to know if the machine is open or closed in a particular moment
Accumulation of residue in the machine Oil does not provide enough heat for distillation	Connected flow and level sensors Connected oil level sensors (ultrasound or float)	To be able to know the volume of residue in the machine To be able to know the volume of oil in the machine

SOURCE: Zancul et al. (2016, p. 316)

Furthermore, Zancul et al. (2016, p. 310) work used a tool named “Configurator of PSS proposals” to support the company decisions regarding PSS Business strategy.

Therefore, the proposed method was able to take into consideration the potential IoT technologies emerged from FMEA application while developing new business modeling. (BARQUET, 2015; ZANCUL et al., 2016, p. 310, 311, 317).

The company issues related to process redesign that resulted from the Zancul et al. (2016, p. 317) method, represented important insights for this research while enabling the innovation of PSS that comprises IoT solutions. Furthermore, the results were applied to the real case of a machinery company that led to five impacted business process (Zancul et al., 2016, p. 329), as follow:

- Remote machine setup: where the technical team can operate remotely to parameterize the machine set-up;
- Corrective and predictive maintenance: where the company can track machine conditions, and act to correct or to prevent technical problems;
- Material supply: where the company can anticipate the requirement for spare parts, by monitoring the machine conditions;
- Pricing: where the company can apply a pricing strategy that takes into consideration the pay-per-service unit system, by monitoring the machine use;
- Information reporting: where productivity reports can highlight the impact the machine is causing on customers' business.

2.3 PSS design

2.3.1 *Different approaches*

Besides generating value while creating customer utility, the PSS offer also has to be competitive and satisfy customer needs continuously in a multi-dimensional business environment (MONT, 2004, p. 71). The author proposed a framework to evaluate several PSS dimensions such as PSS elements, PSS feasibility, Institutional framework, cultural context, and internal organizational structures and changes, which clearly states the multi-dimensional aspect of a PSS offer life cycle, as depicted in Figure 11.

Figure 11 – Framework for analyzing product-service systems

SOURCE: Mont (2004, p. 71)

Considering that PSS value has to be continuously delivered creating customer utility while achieving a balance between product realization time, cost, and quality, it is required the use of life-cycle oriented service design schemes for both product and services (AURICH; FUCHS; WAGENKNECHT, 2006, p. 1481, 1482). Morelli (2003, p. 98), proposed that a design of a new PSS “requires an extension of the traditional designer’s competence into new logical domains,” originated from the interaction between the designer and customers to synthesize solutions emerging from different points of view and needs, and social-cultural models. Thus, the theoretical knowledge related to the PSS’s design and conceptualization models must be better understood.

PSS design represents a new challenge for designers because “the focus of the design activity shifts from the definition of new products to the re-organization of existing elements by new needs and values” (MORELLI, 2003, p. 75). In that sense, the Vasantha et al. (2012, p. 641) PSS design methodologies review described the main issues that need to be addressed in methodologies, to generate and evaluates PSS design:

- Identification of the stakeholders’ requirements during the offering life cycle;
- Identification of compromises and conflicts between products and services;

- The process for developing integrated solutions for products and services must consider the overall functionality to be delivered;
- The evaluation of developed PSS concepts must take into account product functionality and service behavior during the whole PSS life cycle.

According to Aurich; Fuchs; Wagenknecht (2006, p. 1483, 1484, 1485), the classical design process of technical services must be replaced by a systematic design approach, and product and services design activities must be linked, parallelized and integrated. The concept development phase must use systematic creativity methods to generate the most promising services solutions concerning the corresponding product and final customer (AURICH; FUCHS; WAGENKNECHT, 2006, p. 1486). However, according to Tan (2010, p. 86) the involvement over time of customers, partners and suppliers must be detailed.

Nemoto et al. (2015, p. 1281) proposed a framework for “managing PSS design knowledge,” represented by five elements:

- Core product, which represents the physical product with high relevance for the PSS value proposition;
- Need, which is related to both the core product requirements and customer needs;
- Function, which provides the content to fulfill the need;
- Entity, which represents the “physical and human resources required to prepare, operate and maintain the PSS offering”;
- Actor, which represents every individual or group, engaged in the PSS activities.

Regardless the fact that Nemoto et al. (2015) framework addressed the involvement of actors such as customers, partners, and suppliers, it does not address deeply the services and the customer activities provisioned by both the core product and the services. In that sense, Geum and Park (2011, p. 1602) proposed a PSS Blueprint as a new design tool for PSS, focusing on the “product behavior, service activities, and underlying supporting activities”, thus providing a clear view of the use of the product and service flow during the whole life cycle from management to customer, as well as the “relationship between products and services”. The previous authors stated that

the service blueprint has an important role in PSS design, especially while considering the need for detailed design (GEUM; PARK, 2011, p. 1603).

Geum and Park (2011, p. 1604) defined the proposed PSS blueprint as “a map that portrays the product-service system where products and services are systematically integrated to deliver both sustainability and increased customer value.” The main elements of the PSS blueprint proposed by the previous authors are depicted in Figure 12, and the PSS characteristics that are related to these elements are depicted in Table 3.

Figure 12 – Framework for analyzing product-service system

SOURCE: Geum and Park (2011, 1608)

Table 3 – PSS characteristics and corresponding consideration

PSS characteristics	Corresponding consideration in the product-service blueprint
Product-service integration	Employing the differentiated areas: product area, service area, and supporting area to provide the activity and process of PSS
Transfer of ownership	Incorporating the “point of ownership transfer” and “point of no ownership transfer”
Sustainability	Incorporating the “point of sustainability achieved” to provide how the PSS gain the sustainability
Economic value	Incorporating the “point of economic value achieved” to provide the position and type of value creation (whether the economic value is achieved by providing function, by purchasing, or by managing the products)
The concept of value chain	Including various actors in a network-shaped and incorporating the “point of actor transfer”

SOURCE: Geum and Park (2011, p. 1608)

It is important to notice that according to the previous authors the PSS value is delivered by service provisioning and that in the most cases the “role of the product is transferred to the service as a form of the function” (GEUM; PARK, 2011, p. 1608). One very detailed application of the proposed PSS blueprint was the Car-Sharing PSS offering as depicted in Figure 13 (GEUM; PARK, 2011, p. 1611).

However, even when PSS design uses a detailed blueprint illustrating the product behavior, and both the services and supporting activities that are needed to provide continuous value to the customer, there is still a need to understand how PSS may produce new business opportunities and competitiveness. Therefore, considering that PSS is based on a process of continuous company’s resource improvement, it is important to understand how PSS activities are related to the different levels of the organization (COLLOPY; HOLLINGSWORTH, 2011; MANZINI; VEZZOLI, 2003; TAN, 2010).

To discuss how the different activities of a PSS are developed in different levels of the organization, involving suppliers, partners and customers, Tan (2010, p. 189) proposed a PSS perspective related to the organization business strategy, as depicted in Figure 14. A very important aspect regarding this approach is to highlight the actor's network role, which must take part in every value chain during the PSS's life cycle.

Figure 14 – PSS's Business strategy perspective

SOURCE: Tan (2010, p. 189)

Tan (2010, p. 205) stated that the PSS also has strategic design characteristics that have close relationships with the organization's business strategy, such as resource efficiency strategy; responsibility or management of product life phase; support or management of customer lifecycle activity; partner or collaborate with actor; availability of offering; degree of integration; and revenue mechanism.

Furthermore, Tan (2010, p. 172) proposed a meta-model for PSS conceptualization, as depicted in Figure 15. The proposed meta-model for PSS conceptualization comprises three PSS design dimensions whose behavioral properties when integrated define the effects of the entire system.

Figure 15 – Meta-model for PSS conceptualization

SOURCE: Tan (2010, p. 172)

The three essential design dimensions to support PSS conceptualization proposed by Tan (2010, p. 168, 211), are:

- **Customer Activities:** allow designers to consider the activities that customers must go through to get the PSS value, representing the “user/customer needs dimension.”
- **Product Life Cycle Systems:** allow designers to consider the design of the system and channels that incorporates the product, representing the “product and supporting technologies dimension.”
- **Actor’s Network:** allows designers to consider all the actors involved in delivering the life phase systems and supporting the customer activities, representing the related “business dimension.”

The broadly used Osterwalder and Pineur (2010, p. 14) Business Model Canvas building blocks and types, outlines design dimensions that can be related to the three PSS design dimensions described by Tan (2010, p. 175, 205). For instance, the “Customer Relationships” Canvas building block can be related to the “Customer Activities” aforementioned dimension; The “Key Resources” building block can be related to the “Product Life Cycle Systems” aforementioned dimension; and the “Key

Activities, “Key Partners”, and “Distribution Channels” can be related to the “Actors Network” aforementioned dimension.

Osterwalder and Pineur (2010, p. 14) stated that “a business model describes the rationale of how an organization creates, delivers, and captures value.” The proposed nine “building blocks” that compose the Business Model Canvas are depicted in Figure 16 (OSTERWALDER; PIGNEUR, 2010, p. 16).

Figure 16 – Business Model Canvas

SOURCE: Osterwalder and Pigneur (2010, p. 18, 19)

Barquet (2015, p. 60, 61, 63) adopted the Business Model Canvas to propose a method named “Configurator of PSS Proposals,” to guide the creation of PSS proposals within the context of a PSS Business Model Design. This method was a result of a very comprehensive study regarding the identification of attributes that should support a PSS proposal creation. The method above was used as a tool by ZANCUL et al. (2016, p. 310) to support the company decisions regarding PSS Business strategy, as described in section 2.2.2, p. 35, of this research.

The steps, inputs, and outputs of Barquet (2015, p. 62) proposed method are depicted in Figure 17.

Figure 17 – Configurator of PSS Proposals

SOURCE: Barquet (2015, p. 62)

Table 4 – PSS characteristics and corresponding consideration

Acronym	Meaning
PA	Partners
MS	Market/ Customer Segment
KR	Key Resources
KA	Key Activities
VP	Value Proposition
CR	Customer Relationship
DC	Distribution Channel
RS	Revenue Streams
CS	Cost Structure

SOURCE: Barquet (2015, p. 62)

Gelbmann and Hammerl (2015, p. 51) also used the Business Model Canvas to investigate, amongst other research questions, the elements of products and services that are involved in re-use based Sustainable PSS (SPSS). Likewise, França et al. (2017, p. 156, 157) proposed a “Framework for Strategic Sustainable Development” (FSSD) that uses the Business Model Canvas (OSTERWALDER; PIGNEUR, 2010, p. 16), as an approach for the PSS business model design.

Tukker (2015, p. 88) stated in his recent comprehensive PSS review that the most important contribution of the literature produced after 2006 is “probably the strong attention to what PSS development means for a company’s structure, culture, capabilities, and management.”

2.3.2 *The role of Business Model Design*

Teece (2010, p. 173) made a strong argument regarding the role of Business Model Design while stating that “To profit from innovation, business pioneers need to excel not only at product innovation but also at business model design.” However, just the design of a new business model is not enough to achieve a competitive advantage. The new business model must represent market differentiation based on new ways to create and capture value to stakeholders while creating barriers for new entrants (CASADESUS-MASANELL; RICART, 2010, p. 1; SPIETH et al., 2014, p. 244; TEECE, 2010, p. 173).

Euchner and Ganguly (2014, p. 34) reinforced the importance to design business models able “to capture value from innovation inside a corporation”, while (SPIETH et al., 2014, p. 243) stated that there is still a lot to learn about how the process of designing business models will be able to capture new opportunities in ever-changing environments.

França et al. (2017, p. 165) proposed a framework that used Business Model Innovation and Design to provide the means to achieve sustainability strategies for PSS. The previous authors highlighted a suite of business objectives that are strengthened while using that combined approach, as follow:

- Scalability, to avoid to develop a business unable to scale to a global level;
- Risk avoidance, to clarifies previously “invisible risks” during the business model development process;

- Investment Strategy, to generate and prioritize action “into flexible platforms for sustainable business success”;
- Partnerships and Social Integration, to identify “partnerships, relationships, cooperative activities and integration across an enlarged group of social institutions that are increasingly important to business success.”

The widely cited Vasantha et al. (2012, p. 641) review of PSS design methodologies, defined “the design process of creating business models” as one of the main design stages of the PSS Design, as well as the “influences of business models on the integrated solutions.” The other PSS design stages defined by the previous authors are the design process for the integration of products and services; the incorporation of multi-disciplinary approaches; and the specification of differences in the design process for different types of PSS (VASANTHA et al., 2012, p. 641, 642).

However, the Vasantha et al. (2012, p. 646) maturity model that resulted from the analysis of the PSS methodologies proposed in the literature, demonstrated that “the design of innovative business model” as well as the “influences of business models on product and services offers” were almost never considered, as depicted in Figure 18.

Figure 18 – Relative maturity of various issues considered in PSS domain

SOURCE: Adapted from Vasantha et al. (2012, p. 646)

2.3.3 PSS Transition Framework

As defined in section 1.1 this research is aligned with the “PSS Transition Framework” proposed by Pieroni et al. (2016, p. 414, Fig. 1), and aims to contribute while adding to it the “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)”

The Pieroni et al. (2016, p. 413) “PSS Transition Framework” comprises several different methods and tools to “support manufacturing companies in the transition from traditional product to PSS business model.” The Business Model Design represented a core activity within the proposed framework, based on the assumption that the transition to PSS always involves the proposition of a new Business Model (PIERONI et al., 2016, p. 413).

The Pieroni et al. (2016, p. 413) framework’s Business Model Design was based on both the “Business Model Canvas proposed by Osterwalder and Pineur (2010, p. 14), which was discussed in section 2.3.1 and depicted in Figure 14, and the “Configurator of PSS Proposals” proposed by Barquet (2015, p. 62), which was also discussed in section 2.3.1 and depicted in Figure 15.

The “PSS Transition Framework” phases, methods and tools are depicted in Figure 19. This research aims to add the “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)”, which is supposed to be used during the “Value Proposition Phase” and the “Initial Business Model Phase” (PIERONI et al., 2016, p. 414, 415). Therefore, the other phases, method, and tools of this framework were not subject to investigation in this research.

The Value Proposition Phase unites customers, stakeholders, and designers and uses Design Thinking (DT) methodology adapted from the Bootcamp Bootleg methodology, to identify the insights, needs, opportunities and problems that could be addressed by the value proposition (PIERONI et al., 2016, p. 415; PIERONI, 2017, p. 136; PLATTNER, 2010). Furthermore, the team proposes ideas to solve the identified shortfalls, needs, and new opportunities, and the best ideas are combined into concepts that are tested by the customers

Figure 19 – PSS Transition Framework

SOURCE: Pieroni et al. (2016, p. 413)

The Design Thinking (DT) methodology used in the “Value Proposition” phase of the “PSS Transition Framework,” presented the following steps:

- a. Understand customers and stakeholders to create empathy and identify issues;
- b. Define which issues should be solved as a value of the PSS;
- c. Ideate solutions for the PSS;
- d. Test the ideas with customers, and improve the best PSS solutions according to customer’s feedbacks.

The Initial Business Model Phase uses a tool based on the aforementioned Canvas Business Model and the Configurator of PSS proposals, to generate options of Business Models able to address the value proposition, and the customer segment, defined in the previous Value proposition Phase (BARQUET, 2015, p. 62; OSTERWALDER; PIGNEUR, 2010. p. 14; PIERONI et al., 2016, p. 415).

The Business Model dimensions used in the “Initial Business Model” phase depicted in Figure 19 are described below.

- a. Strategy
- b. Customer Segments
- c. Value Proposition
- d. Channels
- e. Customer Relationship
- f. Processes
- g. Partnerships
- h. Resources
- i. Revenue
- j. Costs
- k. Economic Viability

This research aims to use the tools and activities that comprise the phases above while adding the proposed “A Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)” to the “PSS Transition Framework.”

2.4 Synthesis of the literature review

As described in section 3.2.2.2 (DS Activity 2: Synthesize literature), in this section the literature review was synthesized to identify how the research question (How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”?) is addressed.

From the PSS perspective discussed in section 2.1 (Product-Service Systems (PSS)), it represents profound changes in how a company provides value to its customers and also regarding the changes within the organization, to provide value during the whole offering life cycle rather than just selling the products. One of the insights that emerged is related to the labor-intensive aspect of a PSS Business Model, and how that aspect can represent a barrier for PSS adoption because the costs necessary to provide services to the customer, during the offering whole life cycle (TUKKER, 2015, p. 88).

The IoT bundle of technologies described in section 2.2.1 (Internet of Things (IoT)) can address the labor-intensive characteristic of a PSS Business Model while providing solutions with potential to present autonomous and proactive behavior, context awareness, collaborative communications, and elaboration.

The information synthesized from section 2.2.2 (IoT applications enabling new value proposition to PSS) showed that IoT technologies represent an enabler to PSS, and that PSS business model is considered as an important scenario to an IoT offering, sometimes named as PaaS (Product as a Service). One important driver for this synergy between PSS and IoT may rely on the characteristics of a typical IoT offering, which may comprise a complex bundle of different, products, services and systems.

One important challenge represented by a PSS comprising IoT solutions is related to its capability to achieve Business Performance. The IoT integration into PSS has the potential to add more efficiency in PSS business processes. However, that potential should be identified considering the entire range of smart products capabilities,

described by Porter and Heppelmann (2014, p. 8). However, the most often found approach in these references is related to the communication stacks, service-oriented architecture (SOA), cloud-based applications, and other very technical descriptions regarding the IoT objects (ATZORI; IERA; MORABITO, 2010; GUBBI et al., 2013; MIORANDI et al., 2012; PORTER; HEPPELMANN, 2014). Moreover, when the same references refer to the IoT potential applications for industries such as “Transportation and Logistics,” and “Healthcare,” it is used a high-level textual description to describe them (ATZORI; IERA; MORABITO, 2010, p. 2793).

The literature related to PSS design has many different approaches as described in section 2.3.1 (Different approaches), most of them focused on the challenge of the joint design of the products and services that comprise the PSS. There are also many references describing the relations between the product and the flow of services, underlying supporting activities, and actors involved to deliver the value proposition during the whole life cycle, from the management to the customer. These aforementioned approaches include from meta-models for PSS conceptualization to integrate all these activities, to very detailed PSS blueprints that provides a graphic view of the PSS’s flow of products, services, actors and supporting activities.

Furthermore, the PSS characteristics related to the organization’s Business strategy were also discussed in section 2.3.1, and are directly related to the research question. The often used approach was to use of Business Model Canvas Business Model Canvas for the PSS Business Model Design (OSTERWALDER; PIGNEUR, 2010, p. 16). This approach is used by this research while being part of the “PSS Transition Framework” described in section 2.3.3. However, to answer the research question, the detailed IoT characteristics must be represented while detailing the PSS Business Model.

The importance of using Business Model Design to identify new value proposition of IoT application into PSS was also described in section 2.3.2 (The role of Business Model Design). However, there are few examples of frameworks able to identify new value proposition from IoT application into PSS, using Business Model Design activities. Some references were focused on the architecture phase, generating IoT alternative solutions while providing a method to support the decision-making process to choose the best alternative. However, these approaches were not focused on analyzing the impact of these solutions on the company’s Business Model. Other

references were able to analyze the impact of IoT on the overall PSS Business Model, but focusing just on the monitoring and control levels of smart products capabilities.

Whilst considering the gaps mentioned above, this research aims to propose a method able to represent every kind of IoT's applications capabilities, from monitoring and control to optimization and autonomy. Furthermore, the information generated by the common IoT representation must be detailed and added to each PSS Business Model Dimension.

3 Methodology and research structure

The objective of this chapter is to describe the methodology by which this research was conducted. It is organized in two sections: section 3.1 gives an overview of the general methodological approach, while section 3.2 describes the research structure specifying methods and tools applied in each activity.

3.1 Methodological Approach

While the process of design has the objective to develop a solution to fulfill an identified need, the design research has the objective to formulate and validate models and theories about design and improve design practice. The objective of this research is to propose a method to help designers, regarding the identification of an IoT representation able to help designers during the PSS Business Model Design. Therefore, this research is aligned with the design research concept (BLESSING; CHAKRABARTI, 2009, p.12).

The Design Research Methodology (DRM) framework provides process steps to help the design research planning, as well as guidelines to help the development of more rigorous research, thus improving the chances of reaching valid results. In that sense, DRM was selected to support this research (BLESSING; CHAKRABARTI, 2009, p.14).

The DRM framework encompasses four stages:

- Research Clarification (RC): At this stage, the researcher must search the literature for evidence that may support the research assumptions and goals. Based on the evidence found, the initial descriptions of both current and desired situations are developed, and some criteria are formulated to verify the outcome of the research (BLESSING; CHAKRABARTI, 2009, p.15).
- Descriptive Study I (DS-I): At this stage, the researcher reviews the literature and develop logical reasoning to improve task clarification, while identifying the influencing factors that should guide to the proposition of the future solution (BLESSING; CHAKRABARTI, 2009, p.16).
- Prescriptive Study (PS): At this stage, researchers can propose a solution for the desired scenario, while considering that the elaboration of this solution may revisit previous stages. However, to verify if the proposed solution is

compliant with the research objective, it will be needed an assessment step that is described in the fourth stage (BLESSING; CHAKRABARTI, 2009, p.16).

- Descriptive Study II (DS-II): At this stage, researchers can evaluate if the proposed solution is compliant with the desired scenario, identify the limitations of the design research, and propose further investigations (BLESSING; CHAKRABARTI, 2009, p.16).

The DRM stages can be executed in parallel and perform various iterations during the research process. Moreover, a research process can be initiated in any of the stages and comprise a subgroup of stages, depending on the type of the design research. DRM theory states that there are seven different types of design research, as depicted in Figure 20, and that it is important to identify the research type that is “suitable to answer the chosen research questions and verify hypotheses” (BLESSING; CHAKRABARTI, 2009, p.60).

Figure 20 – DRM types of design research projects

Research Clarification	Descriptive Study I	Prescriptive Study	Descriptive Study II
1. Review-based	→ Comprehensive		
2. Review-based	→ Comprehensive	→ Initial	
3. Review-based	→ Review-based	→ Comprehensive	→ Initial
4. Review-based	→ Review-based	→ Review-based Initial/ Comprehensive	→ Comprehensive ←
5. Review-based	→ Comprehensive	→ Comprehensive	→ Initial
6. Review-based	→ Review-based	→ Comprehensive	→ Comprehensive ↑
7. Review-based	→ Comprehensive	→ Comprehensive	→ Comprehensive ↑

SOURCE: Blessing and Chakrabarti (2009, p.60)

This research has the objective to propose a method to answer the following research question: How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”? Throughout this

research, the reasoning performed within the DS-I stage was sufficient to support a comprehensive PS, which resulted in the proposed method.

This research is focused on the design of artifacts not found together in the literature, to improve the representation of IoT solutions into PSS Business Model Design. Therefore, the research is aligned with “Type 3” DRM type, which is focused on the development of a support “to improve the existing situation” (BLESSING; CHAKRABARTI, 2009, p. 61). A comprehensive PS was performed because the existing literature does not consider the context of IoT representation into PSS Business Model Design. Furthermore, an initial evaluation of the proposed method was performed at the end of the comprehensive PS, instead of a complete initial DS II evaluation. The reason for that adaption was the difficulty to involve for an extended period, a designing team with the necessary skills to evaluate the method using a real case study.

The research methods that were applied to each stage of this research, as well as the deliverables generated in each section of this document, are presented in the next section.

3.2 Research Structure

To orientate and link the methodological approach, the research methods used in each stage, the research deliverables, and in which sections of this document the deliverables can be found, are described in Table 5.

Table 5 – Research Structure Summary

Methodological approach	Research Methods	Research Deliverables	Sections of the Document
Stage 1: Research Clarification (RC)	- Literature review	D.1.1 - Research context and justification D.1.2- Research question and objective D.1.3 - Research Methodology	D1.1 – Section 1.1 D1.2 – Section 1.2 D1.3 – Chapter 3
Stage 2: Descriptive Study I	- Literature review - Synthesis from the literature review	D.2.1 – Literature Review D.2.2 – Synthesis of the literature review	D2.1 – Sections 2.1, 2.2, 2.3 D.2.2 – Section 2.4
Stage 3: Prescriptive Study	- Review based on the synthesis from the literature - Literature review based on research questions - Secondary sources of multiple case studies - Exploratory Retrospective Case Study from literature and Confirmatory Focus Group (CFG)	D.3.1 – Requirements for the proposed method D.3.2 – Method’s artifacts development D.3.3 – Exploratory Application of the Method D.3.4 – Evaluation of the method with a Focus Group	D.3.1 - Section 4.2 D.3.2 - Section 4.3 D.3.3 - Section 4.5 D.3.4 – Section 4.6

SOURCE: Created by the author

3.2.1 Research Clarification (RC)

Research Clarification stage aims to define the research problem, research question, research objective, and the methodological approach.

The research method is review-based, and it was executed using a literature review, encompassing the main themes of the present research: Product-Service System (PSS), Application of Internet of Things (IoT) in PSS, and PSS design with a focus on the PSS Business Model Design.

This stage generated the following deliverables: *Research context and justification* (D.1.1), which is presented in section 1.1; the *Research question and objective* (D.1.2), which is presented in section 1.2; and the *Research methodology* (D.1.3), which is presented in chapter 3.

3.2.2 Descriptive Study I (DS-I)

Descriptive Study I stage aims to develop a detailed description of the existing situation to improve task clarification and to synthesize information, which will support the proposition of the Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS).

The research method is review-based, and it was executed using two activities: to review the literature and to synthesize the information that emerged from the literature review. The methods and tools that supported each activity are presented in the next sections.

3.2.2.1 *DS Activity 1: Literature Review*

The literature review was performed to support a deeper understanding regarding the main themes that were discussed during the Research Clarification stage to understand better how to answer the research question: “How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”?”

This search for references was performed with the support of the databases Scopus and Web of Science. The selection of references was based on the keywords related to the main themes that were identified during the Research Clarification stage, from where the most cited papers were chosen. Based on this first group of references, an initial filter based on an analysis of the relevance of the title, abstract, and conclusion was performed. After this filter, the entire papers of the second sample of references were considered for reading.

Regarding the PSS topic the search strings used were (("Product-Service System" OR "product service system" OR ("product-service" AND system)) OR ("software as a service") OR (servitization)),, as well as ((PSS AND Design) AND (PSS AND Business AND model AND (design OR development OR representation))).

It is important to notice that while searching references using the keywords “PSS” AND “IoT” very few results were found (46), as depicted in Table 6, and amongst these references even fewer were considered relevant to answer the research question (7).

Table 6 – Search for “PSS AND IoT” references

Search String	References found Web of Science Database	References found Scopus Database
S1 = (("Product-Service System") OR ("product service system") OR ("product-service" AND system) OR ("software as a service") OR (servitization))	2770	3047
S2 = ("internet of things")	10716	19501
S1 AND S2	46	61

SOURCE: Created by the author

Therefore, another search was performed to acquire more knowledge regarding the theme “IoT applications enabling new value proposition to PSS”:

- ((("IoT" OR "internet of things") AND ((business AND model) OR ("Creating Customer Value")))) Limited to the period initiating in 2012
- (("internet of things") OR (iot)) AND ("business model innovation")

The results are depicted in Table 7

Table 7 – Search for “IoT and Business Model or Creating Customer Value and PSS” references

Search String	References found Web of Science Database	References found Scopus Database
S1 = ((("IoT" OR "internet of things") AND ((business AND model) OR ("Creating Customer Value")))) AND (PSS OR product-service AND system OR servitization)	7	53

SOURCE: Created by the author

The *Literature Review Derivable* (D.2.1) is presented in sections 2.1, 2.2, 2.3

3.2.2.2 DS Activity 2: Synthesize literature

The objective of this activity is to synthesize the literature review to identify how the research question is addressed, regarding the context of the use of IoT technologies, and the use of Business Model Design within the PSS Design. Thus, being able to support the identification of which parts of the problem are not currently addressed (BLESSING; CHAKRABARTI, 2009, p. 61).

The synthesis of the literature review deliverable (D.2.2) is presented in section 2.4, and contains the discussion that was used to support the PS Activity 1 – Requirements for the proposed method.

3.2.3 Prescriptive Study (PS)

The objective of this stage is to support the elaboration and an initial evaluation of the “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS).” This research adapted the five steps of the systematic PS process proposed by Blessing and Chakrabarti (2009, p. 146). The following adaptations were made, and depicted in Figure 21.

Figure 21 – PS stages adapted

SOURCE: Adapted by the author from Blessing and Chakrabarti (2009, p. 146)

3.2.3.1 PS Activity 1 – Requirements for the proposed method

The objective of this activity is to identify the requirements that must be attended by the “Method to support the representation of IoT solutions during the PSS Business Model Design.” They were developed based on deliverable “synthesis of the literature review” (D.2.2), presented in section 2.4. The PS Activity1 corresponds to the DRM’s conceptualization PS stage (BLESSING; CHAKRABARTI, 2009, p. 155).

The requirements consider that this research will be part of the existing “PSS Transition Framework” proposed by Pieroni et al. (2016, p. 414).

The Deliverable (D.3.1) is presented in section 4.2 (Requirements for the proposed method)

3.2.3.2 PS Activity 2 – Development of the method’s artifacts

The method fulfills each requirement that resulted from PS Activity 1 using developing a respective artifact (BLESSING; CHAKRABARTI, 2009, p. 164). The requirements for the method defined in PS Activity 1, generates a set of questions to guide the development of the method’s artifacts.

The research methods used to define the artifacts were both based on a review of the literature and also based on the use of multiple retrospective case studies from the literature with secondary sources. Voss et al. (2002, p. 197) define the case study as “a history of the past or current phenomenon, drawn from multiple sources of evidence,” and that case studies are strong on theory building. It is important to use the research questions to guide the theory development (VOSS; TSIKRIKTSIS; FROHLICH, 2002, p. 198).

One of the advantages of adopting case study regards to the possibility to involve a large number of cases, even if these cases came from secondary sources, thus generating useful information for content analysis while performing “cross-case comparisons” (URBINATI; CHIARONI; CHIESA, 2017, p. 492).

Therefore, this research reviewed the literature to identify cases with contrasting characteristics, to “highlight the differences being studied” (VOSS; TSIKRIKTSIS; FROHLICH, 2002, p. 203). Meredith (1998, p. 452) also emphasizes that while using multiple cases, to “include extreme cases and polar types is highly desirable.” These contrasting characteristics of the selected case studies were identified while applying a set of “questions for case study”, which resulted from each one of the requirements for the proposed method that resulted from PS Activity 1.

The criterion used was to select references that described successful real case studies of IoT application into PSS, which were considered as secondary sources to provide the information needed to generate the method’s artifacts, are described below.

- Business process support for IoT based product-service systems (PSS) (ZANCUL et al., 2016)

This reference is based on a real case in the Machinery Industry, and it proposed a method for “adopting IoT-enabled PSS considering the implications for the business model, the product, and related business processes.”

- IoT powered servitization of manufacturing – an exploratory case study (RYMASZEWSKA; HELO; GUNASEKARAN, 2017)

This reference is based on three real cases: Machinery Industry, Power Plants, and Electrical Engineering Operation-Services. This work presented insights into

different ways that IoT creates value in servitization, the business model changes, and which are the selected “smart” capabilities for each case.

- Business models for the Internet of Things (DIJKMAN et al., 2015)

This reference is based on interviews involving 11 companies with IoT offering from different industries, such as Healthcare; Agriculture; Energy; Smart Home; Smart Building; and Supply Chain. The objective of the semi-structured questionnaire applied to the practitioners of these companies was to identify the “completeness and correctness” of IoT Business Model Canvas building blocks and types. The research also performed a survey with 300 responses from which 72 observations were considered for analysis. This work aimed to identify the most important Business Canvas building blocks and types, to be considered in IoT business models.

- Creating customer value for product service systems by incorporating internet of things technology (SHIH; LEE; HUANG, 2016)

This reference uses a real case of a company that provides Battery Swapping Services for Electric Scooters in Taiwan. The work introduced a new concept of “pseudo actor” that describes the objects that incorporate IoT and proposed a design method based on “pseudo actors” concept to help the design of PSSs that incorporate IoT technologies.

Therefore, the discussion that resulted from the application of the “questions for case study” within the four retrospective case studies described above, supported the embodiment of the main functions represented by the requirements for the method that resulted from the PS Activity 1, in such a way that the method can be realized (BLESSING; CHAKRABARTI, 2009, p. 164).

The PS Activity 2 generated the following deliverable: Method’s artifacts development (D.3.2), which is presented in section 4.3 (Method’s artifacts)

3.2.3.3 PS Activity 3 – Method Initial Evaluation

To conclude the PS stage it was performed by the researcher an exploratory application evaluation of the method, using an existing case that was used to apply the method to verify “likelihood of find problems” (BLESSING; CHAKRABARTI, 2009, p. 177).

The exploratory application of the method was performed by the researcher using a PSS Car Sharing example. The PSS car sharing example was used because it is a well-known PSS strategy that has been studied by many researchers (BAINES et al., 2007; GEUM; PARK, 2011; HUWER, 2004; MONT, 2004a, 2004b, 2002). In special, this research used the insights regarding Car Sharing PSS provided by Mont (2004b, p. 141, 142), and the information generated by a very detailed PSS Car Sharing design blueprint provided by Geum and Park (2011, p. 1611, Figure 7).

At this PS activity, all the artifacts of the method, as well as the result of the exploratory application of the method, were presented to a focus group of 10 experts. The objective of the focus group was to perform an initial evaluation of the utility of the method in the application field (TREMBLAY; HEVNER; BERNDT, 2010, p. 602).

Tremblay et al. (2010, p. 601) highlighted four key reasons that reinforce that focus groups represent an appropriate evaluation technique, for evaluation of artifacts that result from design research, as follow:

- Flexibility, to “handle a wide range of design topics and domains”;
- Direct Interaction with Respondents, where “the researcher is put into direct contact with domain experts and potential users of the design artifact”;
- Large Amounts of Rich Data, where the focus group interactions produce both quantitative and qualitative data;
- Building on Other Respondent’s Comments, where the focus group interactions enable the emergence of new ideas.

A Confirmatory Focus Group (CFG) represents a useful technique that is “used to demonstrate the utility of the artifact design in the application field” (TREMBLAY; HEVNER; BERNDT, 2010, p. 602). It is important to recruit experts in the application environment, and potential users of the proposed artifact, to achieve that objective (TREMBLAY; HEVNER; BERNDT, 2010, p. 604). According to the previous authors the following tasks should be performed to control and manage the focus group:

- Select the participants: The participants were selected based on theirs skills of PSS or sustainability or Circular Economy, IoT or Industry 4.0, and Project Management;

- Identify a moderator: The moderator of the focus group that evaluated the proposed method's indication of usability and applicability was the researcher;
- Develop a questioning route: The questioning route was designed for the evaluation of the method;
- Conduct the Focus Group;

The contents of the recorded discussion must be analyzed looking for common themes and variations, which “would provide rich descriptions of the participants' reactions to design features” (TREMBLAY; HEVNER; BERNDT, 2010, p. 605).

The PS Activity 3 generated the following deliverables: Exploratory Application of the Method (D.3.3) is presented in section 4.5, and the Evaluation of the Method with a Focus Group (D.3.4), which is presented in section 4.6.

4 Results and discussion

4.1 Context and purpose

As described in section 1.2 (Research question, and objective), this research proposed method is aligned and aims to be added to the “PSS Transition Framework” proposed by Pieroni et al. (2016, p. 414), described in the section 2.3.3. This framework uses the Business Model Design as one of its core method and tools. Moreover, the context of this research within the “PSS Transition Framework” is focused on the “Value Proposition and Initial Business Model” phases.

4.2 Requirements for the proposed method

As described in section 3.2.3.1 (PS Activity 1 – Requirements for the proposed method), the requirements were developed based on deliverable “synthesis of the literature review” (D.2.2), presented in section 2.4, and described below.

Requirement 1 – To identify an IoT’s object representation

As discussed in section 2.4, one important driver for the synergy between PSS and IoT is related with the specific characteristics regarding the IoT offering, such as its object’s capability to present autonomous and proactive behavior, context awareness, collaborative communications, and elaboration. Thus, neither a too much technical description nor a free textual description of the IoT solution, which are most often found in the literature, can represent the IoT solution most important characteristics during the PSS Business Model Design.

Hence, there is a need to find an IoT’s object representation able to describe the most important characteristics of an IoT application, without using deep technical language hard to be used by the PSS Design stakeholders. While using this intermediate level of representation of an IoT solution, it will be possible to define a common language for a PSS Business Model’s multidisciplinary design team.

Requirement 2 – Modeling language and Tool to support the IoT Function breakdown

After identifying an appropriate IoT’s object representation able to describe its characteristics, it is important also to provide more detailed information related to that representation. As discussed in section 2.4, the IoT solution characteristics must be represented while detailing the PSS Business Model. Thus, while considering the

complex bundle of technologies of a typical IoT solution described by the IoT's object representation, the anticipation of more detailed information to be added to the PSS Business Model will be able to help the designers, in the future evaluation of that IoT potential to enable new value proposition.

Therefore, a modeling language and a tool able to generate more information, using modeling constructs, would bring a formal, well-defined and detailed description of the IoT's object representation, to be used by the Business Model Design Team. However, the information synthesized from the literature showed that few references used a tool able to detail the IoT function. Moreover, these references that proposed a tool to detail the IoT functions were focused on the monitoring and control capabilities of smart products. Thus, not being able to cover every kind of IoT's smart products capabilities, from monitoring and control to optimization and autonomy.

Hence, there is a need to identify a modeling language and tool to support the IoT functionality detailing, taking into account the IoT's object representation characteristics.

Requirement 3 – To relate the detailed information regarding the IoT representation to the Business Model's dimensions

After detailing the information related to the IoT's object representation, it is important to identify which are the most important Business Model's dimensions related to IoT solutions. It is important to help designers to focus on the relation between the IoT representation detailed information, and specific building blocks of a Business Model that are most often used while developing an IoT offering.

Furthermore, the information synthesized from the literature and the literature review discussed in section 2.2.2, showed well-cited references proposing different sets of Business Model's dimensions and types related to IoT offering. However, these different approaches must be aligned with the "PSS Transition Framework" discussed in section 2.3.3, in which this research is inserted. Moreover, to define a subset of Business Dimensions to be fulfilled with information generated by the proposed method may bring efficiency in the use of the method.

Hence, there is a need to define questions that will help designers to focus on relating the detailed information resulted from the IoT's object representation and its

group of modeling constructs to an IoT related subset dimensions of the PSS Business Model.

Requirement 4 – To define a step-to-step logic

The proposed method comprises artifacts that must be defined to fulfill the previous requirements. Once the artifacts are defined, the step-to-step logic of the method must also be defined. The step-to-step logic is needed to define the sequence of use of each artifact by each method's step, the input and outcome of each step, as well the skill of participants and the expected period to perform each step.

4.3 Method's artifacts

As described in section 3.2.3.2 (PS Activity 2 – Development of the method's artifacts), the requirements for the method must be fulfilled by the artifacts that will compose the method. Therefore, each requirement will generate one respective artifact, and the group of requirements together will generate the artifact related to the requirement 4 (to define the method's step-to-step logic).

To facilitate the reasoning that supports the development of each method's artifact, a set of questions were defined to orientate the artifacts development. Moreover, the questions were also used in the multiple case study, which also supports the development of the artifacts related to requirements 3 (To relate the detailed information regarding the IoT representation to the Business Model's dimensions), and 4 (step-to-step logic). The set of questions are depicted in Table 8.

Table 8 – Questions for artifacts development and case study

Research Framework	Questions for the artifacts development	Questions for Case Study
Research Question	How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”?	(1) How did the case identify IoT solutions with potential to create new value proposition to PSS?
Requirement 1 To identify an IoT’s object representation	How to represent the main characteristics of IoT functionality in a replicable way, while covering every type of smart product capability?	(2) How did the case represent or describe an IoT object?
Requirement 2 Modeling language and Tool to support the IoT Function breakdown	How to detail the IoT functionality in a way to provide information to Business Model Design?	(3) At which level of detail did the case describe an IoT function?
Requirement 3 To relate the detailed information regarding the IoT representation to the Business Model’s dimensions	How to relate the detailed information regarding the IoT representation to the Business Model’s dimensions?	(4) Did the case identify the most important Business Model’s dimensions related to IoT? (5) Did the case propose a specific way to relate the IoT solution, to the Business Model’s dimensions?
Requirement 4 To define the method’s step-to-step logic	How the step-to-step logic of the method defines the sequence and usage of the previously defined artifacts?	(6) Did the case propose a specific sequence of steps for the case proposed method of applying IoT into PSS?

SOURCE: Created by the author

4.3.1 Representation of the IoT's object

As discussed in section 4.2 (Requirements for the proposed method - requirement 1), there is a need to find an IoT's object representation able to describe the most important characteristics of an IoT application, without using deep technical language hard to be used by the PSS Design stakeholders. Furthermore, this IoT object representation should comprise attributes able to define its characteristics for every kind of IoT solution that can emerge from the (PORTER; HEPPELMANN, 2014, p. 8) categories of smart products, from monitoring and control to optimization and autonomy. In that sense, it is important also to identify an IoT object representation able to integrate the functionalities provided by heterogeneous objects seamlessly, as described in section 2.2.1 (Internet of Things (IoT)) (MIORANDI et al., 2012, p. 1499).

The main references discussed in sections 2.2.1 and 2.2.2 were scrutinized to answer the question related to requirement 1 depicted in Table 8 (How to represent the main characteristics of IoT functionality in a replicable way, while covering every type of smart product capability?), with the following objectives:

1. To identify which references had identified the need;
2. Amongst those, which IoT object representations were proposed;
3. Amongst the IoT object representations proposed, which ones comprise attributes that could be related to the Business Model dimensions used in the adopted "PSS Transition Framework" (PIERONI et al., 2016, p. 413).

Therefore, the review of the literature was based on the question proposed in section Atzori et al. (2010, p. 2792) stated the need for an abstraction layer to access the functions of heterogeneous IoT objects, with a "common language and procedure." The previous authors proposed two layers to solve that issue, as described below:

1. A standard web interface responsible for the management of all the incoming/outcoming messaging operations to communicate with the external world;
2. An application that implements the logic behind the web service methods and translates these methods into a set of device-specific commands.

These two layers involve communication stacks, proxies, and sockets that can be provided by different technical standards, thus being focused on the IoT solution architecture phase definition. This approach makes it difficult to relate the information to the Business Model dimensions (ATZORI; IERA; MORABITO, 2010, p. 1792; PIERONI et al., 2016, p. 413), as depicted in Figure 22.

Figure 22 – IoT Messaging Communication Stack

Source: Atzori et al. (2010, p. 2800)

Using the same approach of Atzori et al. (2010, p. 2792), the technology stack proposed by Porter and Heppelmann (2014, p. 7) is also focused on the architecture of the IoT solution, and did not provide specific attributes that could be used to relate the information in a clear way to the Business Model dimensions, as depicted in Figure 23.

Figure 23 – The IoT technology stack

SOURCE: Porter and Heppelmann (2014, p. 7)

As discussed in section 2.2.2 (IoT applications enabling new value proposition to PSS), Shih, Lee and Huarng (2016, p. 2) method to evaluate IoT alternative concepts into PSS is focused on the concept selection activity. Moreover, the previous authors' proposed method presents the description of an IoT solution in free textual format, as depicted in Table 9 for a "Case Developing Battery Swapping Services for Electric Scooters in Taiwan" (SHIH; LEE; HUARNG, 2016, p. 8).

Table 9 – IoT Alternative Solutions Description

Number	Type of Flows	Description
A1	information	Riding distance record for the currently used battery
A2	service	Battery provides power (electricity) for the scooter
A3	information	Battery passes riding distance record to the charging station
A4	information	Battery passes remaining power and other records indicating battery efficiency to charging station
A5	information	Charging station provides riding distance, battery remaining power, efficiency records to control center
A6	information	Control center passes summary report and condition of battery to charging station
A7	information	Remaining power and accumulated riding distance of the battery
A8	information	Battery passes current power status of power to scooter
A9	information	Scooter passes current power status to cell phone
A10	information	Cell phone displays power status to users
A11	product	User and service provider swap batteries

SOURCE: Shih, Lee and Huarng (2016, p. 12)

While analyzing the value creation in servitization through the use of IoT, Rymaszewska et al. (2017, p. 101) made a summary of three successful cases companies, that was depicted in Table 1 of this research. However, the previous authors also described the IoT functionality in free textual format, as described below.

- Company A: Production and operations data captured for OEM;
- Company B: Detailed machine-level sensor data;
- Company C: Connecting transformer to intranet access

The Zancul et al. (2016, p. 306) method, as already discussed in section 2.2.2 (IoT applications enabling new value proposition to PSS), comprised of both Business Model Design activities to support the company's PSS strategy, and failure mode and effects analysis (FMEA) to identify what should be monitored in the product (ZancuL et al., 2016, p. 310). However, the previous authors also described the IoT functionality in free textual format, as depicted in Table 2 of this research.

The other references discussed in sections 2.2.1 (Internet of Things (IoT)) and 2.2.2 (IoT applications enabling new value proposition to PSS) did not propose any kind of IoT object representation (BUCHERER; UCKELMANN, 2011; DIJKMAN et al., 2015; GUBBI et al., 2013; LEMINEN et al., 2012; MIORANDI et al., 2012).

As discussed in section 2.2.1 (Internet of Things (IoT)), Kortuem et al. (2010, p. 31) proposed an IoT's "smart object" model that comprises three design dimensions, which seems to comply with Miorandi et al. (2012, p. 1499) and Atzori et al. (2010, p. 2792), as follow:

- Awareness: represents a smart object's ability to understand the context of events and human activities occurring in the physical world; such as plain activities, domain-specific policies, and work processes.
- Representation: represents the core applications model ability to support activities, such as aggregation of information function model, rules-based model and workflow based model.
- Interaction: represents the smart object's "ability to interact with the user"; such as threshold warnings and context-aware task guidance.

The dimensions proposed by Kortuem et al. (2010, p. 31) can provide attributes that could be related to the Business Model Dimensions, such as those adopted in the "PSS Transition Framework," as depicted in Figure 19. Moreover, these attributes can also be related to the "pseudo actor" role described by Shih, Lee and Huarng (2016, p. 2), where the objects of IoT can support or even replace human actors, whose activities have an impact in several Dimensions of a PSS Business Model.

Another important issue addressed by the Kortuem et al. (2010, p. 31) "smart object model," is the capability to represent any category type of smart product described by Porter and Heppelmann (2014, p. 8), as depicted in Figure 24.

Figure 24 – The Smart Object Model related to the Smart Products Capabilities

SOURCE: Adapted from Kortuem et al. (2010, p. 31) and Porter and Heppelmann (2014, p. 8)

A summary of the review of the literature that resulted in the IoT object representation described above is depicted in Table 10.

Table 10 – Summary of IoT object Representation found in the review

Reference	The need for an IoT object representation identified (Y/N)	IoT object representation proposed	Comprises attributes that describe the most important characteristics of an IoT application, covering from monitoring and control to optimization and autonomy capabilities, without using deep technical language? (Y/N)
(BUCHERER; UCKELMANN, 2011)	N	-	-
(DIJKMAN et al., 2015)	N	-	-
(GUBBI et al., 2013)	N	-	-
(LEMENIN et al., 2012)	N	-	-
(MIORANDI et al., 2012)	Y	-	-
(ATZORI; IERA; MORABITO, 2010)	Y	Technical protocol stacks	N
(PORTER; HEPPELMANN, 2014)	Y	High level technology stack	N
(SHIH; LEE; HUANG, 2016)	Y	Free textual format	N
(RYMASZEWSKA; HELO; GUNASEKARAN, 2017)	Y	Free textual format	N
(ZANCUL et al., 2016)	Y	Free textual format	N
(KORTUEM et al., 2010)	Y	Smart Object Model	Y

SOURCE: Created by the author

For each one of the IoT object representation attributes adapted from the Kortuem et al. (2010, p. 31) “smart object model,” this research defined three levels to facilitate the future use in the proposed method, as follow:

- Awareness of real-world events (adapted from “awareness dimension”): Level 1 = Single sensing, corresponding to plain activities; Level 2 = Multiple sensing intra-system, corresponding to domain-specific policies; Level 3 = Multiple sensing inter-systems, corresponding to work processes
- Intelligence of core applications (adapted from “representation dimension”): Level 1 = Aggregation of information, corresponding to single records of related information; Level 2 = Rules based model, corresponding to applications based on rules; Level 3 = Workflows based model, corresponding to applications based on workflows

- Interaction with user (adapted from “interaction dimension”): Level 1 = Status display, corresponding to simple display of information; Level 2 = Thresholds warnings, corresponding to alarms related to pre-defined thresholds; Level 3 = User work guidance, corresponding to the user activities being guided by an autonomous IoT object

It was also created the “Artifact 1 - IoT Representation Card”, which consolidate the IoT Representation's attributes and the range of levels for each one. The “IoT Representation Card” was created to create a common visual language to facilitate the communication, between the PSS Business Model Design stakeholders, as depicted in Figure 25.

Figure 25 – IoT Representation Card (Artifact 1)

SOURCE: Created by the author

4.3.2 Modeling language to detail the IoT's main function

As discussed in section 4.2 (Requirements for the proposed method - requirement 2), there is a need to identify a modeling language and tool to support the IoT functionality detailing, taking into account the IoT's object representation characteristics.

The main references discussed in sections 2.2.1 and 2.2.2 were scrutinized to answer the question related to requirement 1 depicted in Table 8 (How to detail the IoT functionality in a way to provide information to Business Model Design?), with the following objectives:

1. To identify which references had identified the need;
2. Amongst those, which methods and tools were proposed;
3. Amongst the methods and tools proposed, which ones provided the detailing level that can support the Business Model Design, within the “PSS Transition Framework” (PIERONI et al., 2016, p. 413).

Amongst all the references depicted in Table 10 only Zancul et al. (2016) framework and Shih, Lee and Huarng (2016) method, described in section 2.2.2 (IoT applications enabling new value proposition to PSS), used a tool to identify detailed information regarding IoT solutions with the potential to add value to PSS.

The Zancul et al. (2016) framework used the FMEA to identify what should be monitored in the product (ZANCUL et al., 2016, p. 310). Thus, being focused on IoT functionalities related just to monitoring and control, and not being able to support the detailing of other categories of smart products depicted in Figure 9 of this research.

The Shih, Lee and Huarng (2016) method used an adapted actors system map to represent the flow of product, service, and information that occurs between conventional actors and “pseudo actors,” to identify alternative of IoT concepts to be applied in PSS. This approach is focused on the IoT solution architecture, thus not being able to support the Business Model Design.

This research aims to be added to the “PSS Transition Framework,” as described in section 2.3.3 (Framework for PSS Design comprising Business Model Design), which utilized an extended version of the Event Driven Process Chain (eEPC) as a Business Process Modeling Language (BPML). The context related to the adoption of this BPML by the framework was the use in process detailing activities that are part of the Business Process Architecture phase. However, the EPC extended vision used can support not only process modeling, but it is also able to support functions and activities modeling, which is suitable to represent the PSS services responsible for delivering value to the customer.

The aforementioned BPML was used within the “PSS Transition Framework” to detail the activities performed during the Business Process Architecture (BPA) Phase depicted in Figure 19, and using specific “constructs” to represent the Business Process. To support the breakdown of IoT functionalities this research used the functions and events constructs and adding other constructs to fulfill the requirement

These constructs are important because they are suitable to relate the IoT's object representation attributes described in the previous section, to the dimensions of a PSS Business Model. Thus, not representing just simple function decomposition.

The used modeling constructs are described below.

- Function: describe the activities that comprise the IoT function being detailed;
- Event: outcome of the eEPC modeling constructs related to an IoT Representation Card (Artifact 1)
- Normative: to describe company, partners and government definitions, which represent restrictions that must be considered by the IoT function;
- Policy: to describe both private or government regulations that must be addressed by the IoT function;
- Product: to describe resources provided by both the company and partners' products, which are needed to support the IoT function being detailed;
- Service: to describe resources provided by both the company and partners' services, which are needed to support the IoT function being detailed;
- System: to describe resources provided by both the company's and partners' systems, which are needed to support the IoT function being detailed;
- Risk: to highlight the critical risks that may emerge from the application of the IoT function being detailed.
- IoT's Object Attribute: A new construct was created to represent each attribute of the IoT Representation Card (Artifact 1) presented in section 4.3.1.

This research is also adopting a modeling tool to support the extended view of EPC, which is already adopted by the "PSS Transition Framework," called ARPO (PIERONI, 2017, p. 155). This tool was used by this research to enable a graphic representation of the IoT function breakdown. The first level is represented by a main high-level function free textual description, which would be detailed in one or more levels of function breakdown if needed, as depicted in Figure 26. The last level of function breakdown is then represented by the IoT's Representation Card and its related modeling constructs (Artifact 2), as depicted in Figure 27.

Figure 26 – IoT Main Function breakdown (optional)

SOURCE: Created by the author

Figure 27 – eEPC Constructs to detail the IoT Representation Card (Artifact 2)

Source: Created by the author

4.3.3 Relationship between the IoT Representation detailed information and the Business Model's dimensions

As discussed in section 4.2 (Requirements for the proposed method - requirement 3), there is a need to define questions that will help designers to focus on relating the detailed information resulted from the IoT's object representation and its group of modeling constructs, to an IoT related subset dimensions of the PSS Business Model.

To develop an Artifact able to attend the requirement 3 described above, it was used the research method described in section 3.2.3.2 (PS Activity 2 – Development of the method's artifacts), where successful cases of application of IoT to PSS were scrutinized from literature while performing "cross-case comparisons" (URBINATI; CHIARONI; CHIESA, 2017, p. 492). The comparisons between the different

references were made using the questions depicted in Table 8 , which were deployed from the requirements presented in section 4.2.

The development of this artifact was based on the questions for case study (4) and (5) depicted in Table 8 as described below.

Regarding question (4) (Does the case identify the most important Business Model's dimensions related to IoT?), as discussed in section 2.3.3, the “PSS Transition Framework” related Business Model Design was based on both the “Business Model Canvas proposed by Osterwalder and Pineur (2010, p. 14), and the “Configurator of PSS Proposals” proposed by Barquet (2015, p. 62), and generated a set of Business Model dimensions that were used in the “Initial Business Model” phase. The proposed Business Model Dimensions are described below.

- a. Strategy
- b. Customer Segments
- c. Value Proposition
- d. Channels
- e. Customer Relationship
- f. Processes
- g. Partnerships
- h. Resources
- i. Revenue
- j. Costs
- k. Economic Viability

Considering that the proposed method is part of the “PSS Transition Framework,” the dimensions described above were used as constructs to support the comparison between the four selected case studies, described in section 3.2.3.2 (PS Activity 2 – Development of the method's artifacts).

While analyzing the criteria used by Rymaszewska et al. (2017, p. 97) to collect information regarding the three manufacturing companies, using the constructs

described above it was possible to identify the following sub-set of criteria related to Business Model Design:

- Embedding functionalities: product and cloud (related to resources);
- Development of capabilities performed in-house or externally (related to partnerships);
- Full or partial disintermediation of distribution channels/service networks (related to channels);
- Business model change (related to the overall Business Model Dimensions information);
- Entering new markets by monetizing product data by selling it to outside parties (related to revenue);
- Expanding the company's scope (related to strategy).

The Zancul et al. (2016) framework performed an approach very similar to the “PSS Transition Framework,” including the use of the “Configurator of PSS Proposals tool.” This approach was used to evaluate the changes on each Business Model Dimension due to the application of the identified IoT solutions, thus also reinforcing the use of the Business Model Dimensions defined by the “PSS Transition Framework.” The Business Model Dimensions proposed by the previous authors that presented improvements by the application of IoT technologies are described below, as well as how they related to the dimensions of the “PSS Transition Framework.”

- Value proposition (related to value proposition);
- Customer relationship (related to customer relationships);
- Network (related to partnerships);
- Resources (related to resources);
- Revenue streams (related to revenue);
- Cost Structure (related to costs);

Dijkman et al. (2015, p. 672) work that identified the most important Business Canvas building blocks and types to be considered in IoT business models, as discussed in sections 1.1 (Context and justification) and 2.2.2 (IoT applications enabling new value proposition to PSS) of this research, provided important insights to answer

“question 4”. As described in section 3.2.3.2 (PS Activity 2 – Development of the method’s artifacts), the previous author's work was based on both a comprehensive survey with 300 responses and 72 observations considered in the analysis. The previous work presented below the combined outcome, regarding the most important Business Model Canvas Dimensions to be considered by IoT offering, as well as how they related to the dimensions of the “PSS Transition Framework”:

- Value proposition (related to value proposition);
- Key Partners (related to partnerships);
- Customer relationships (related to customer relationships);
- Customer segments (related to customer segments);
- Revenue streams (related to revenue);
- Cost structure (related to costs).

The comparison of the results of the studies described above with the Business Dimension Definition of the “PSS Transition Framework” is depicted in Table 11, where the Shih, Lee and Huarng (2016) proposed method did not appear because it presented no Business Model Dimensions to be considered.

Table 11 – Comparison of the Business Model Dimensions used by each work

“PSS Transition Framework” Business Model Dimensions	Rymaszewska et al. (2017) Business Model Dimensions	Zancul et al. (2016) Business Model Dimensions	Dijkman et al. (2015) Business Model Dimensions
Strategy	Expanding the company's scope		
Customer Segments	-		Customer segments
Value Proposition	-	Value proposition	Value proposition
Channels	Full or partial disintermediation of distribution channels/service networks		
Customer Relationships	-	Customer relationship	Customer relationships
Processes	-		
Partnerships	Development of capabilities performed in-house or externally	Network (New Partnerships)	Key Partners
Resources	Embedding functionalities: product and cloud;	Resources	
Revenue	Monetizing product data by selling it to outside parties	Revenue streams	Revenue streams
Costs	-	Cost Structure	Cost structure
Economic Viability	-		

SOURCE: Created by the author

This research used a criteria to consolidate the answer for question for case study (4) depicted in Table 8 and define the Business Model Dimensions to be used in to fulfill the requirement 3 described in section 4.2. The defined criteria was: At least three references pointing to the same Business Model Dimension, or just two references if one of them is part of Dijkman et al. (2015, p. 672) comprehensive survey and selected interviews. The result is then highlighted in the gray area in Table 11.

Regarding question for case study (4) depicted in Table 8 (Does the case propose a specific way to relate the IoT solution, to the Business Model's dimensions?), while analyzing the four references that described successful implementations of IoT offerings in PSS Business Model, no one proposed a specific way to relate the identified IoT solutions with the Business Model Dimensions. Considering that the detailed main function will be represented by specific attributes, each one with three levels of complexity, there is a need to propose another Artifact able to deal with this level of representation, while relating the information generated with the sub-set of

Business Model's dimensions of the "PSS Transition Framework", depicted in the gray area of Table 11.

Therefore, besides the definition of the Business Model Dimensions depicted in Table 11, it is also necessary to consider the detailed information regarding each IoT Representation Card (Artifact 1) depicted in Figure 25 , together with its related eEPC constructs (Artifact 2) depicted in Figure 27 .

Therefore, to help designers to focus on relating the detailed information resulted from the IoT's object representation and its group of modeling constructs to an IoT related subset dimensions of the PSS Business Model, the Artifact 3 was defined. The "Artifact 3" comprises a set of questions that relate each IoT Representation Card Attribute level, and the detailed information provided by the related eEPC modeling constructs, to the defined Business Model Dimensions, as depicted in Table 12.

Table 12 – Questions to relate the IoT Representation detailed information to the Business Model Dimensions (Artifact 3)

Business Model Dimensions	Awareness of real-world events	Intelligence of core applications	Interaction with user
Customer Segments	-	Will the proposed level of intelligence of core applications enable a new customer segment?	Will the proposed level of interaction with the user enable a new customer segment?
Value Proposition	-	Which values are addressed by the proposed level of intelligence of core applications?	Which values are addressed by the proposed level of interaction with the user?
Customer Relationships	-	Is the proposed level of intelligence of core applications able to provide automated services?	Are the automated services resulting from the proposed level of interaction with the user able to replace personal assistance?
Partnerships	Which are the partnerships related to the third party solutions, needed to compose the proposed level of real-world events awareness?	Which are the partnerships related to the third party solutions, needed to compose the proposed level of intelligence of core applications?	Which are the partnerships, related to the third party solutions needed to compose the proposed level of interaction with the user?
Resources	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of real-world events awareness?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of intelligence of core applications?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of interaction with the user?
Revenue	-	Will the proposed level of intelligence of core applications enable new revenue streams?	Will the proposed level of interaction with user enable new revenue streams based on the fulfillment of uncovered needs?
Costs	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of real-world events awareness?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of intelligence of core applications?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of interaction with the user?

SOURCE: Created by the author

The “awareness of real-world events” attribute is mostly related to the infrastructure needed to provide the services more efficiently, including the core product functionality, third-party solutions, and their related cost structure. Thus only “Partnerships,” “Resources” and “Costs” were considered to relate with this attribute of the IoT Representation Card.

4.3.4 Sequence of steps for applying the method

As discussed in section 4.2 (Requirements for the proposed method - requirement 4), there is a need to define the sequence of use of each artifact by each method’s step, the input and outcome of each step, as well the skill of participants and the expected period to perform each step.

To compose the proposed method’s step-to-step logic it was used the research method described in section 3.2.3.2 (PS Activity 2 – Development of the method’s artifacts), where successful cases of application of IoT to PSS were scrutinized from literature while performing “cross-case comparisons” (URBINATI; CHIARONI; CHIESA, 2017, p. 492). The comparisons between the different references were made using the questions depicted in Table 8 , which were deployed from the requirements presented in section 4.2.

The discussion regarding question for case study (1) was developed to identify the input for the “method’s step 1”, as described below.

Regarding question for case study (1) (How the case identified IoT solutions with potential to create new value proposition to PSS?), as discussed in section 2.2.2 (IoT applications enabling new value proposition to PSS), Zancul et al. (2016, p. 310) used the FMEA to identify what should be monitored in the product to identify potential IoT solutions for a machinery company. The FMEA tool demonstrated to be a key success factor for that type of IoT application into PSS, generating detailed free textual descriptions of IoT solutions options, as depicted in Table 2. However, the FMEA tool would not be useful to identify other types of IoT solutions, related for instance to the optimization and autonomy capabilities of smart products depicted in Figure 9 –

Rymaszewska et al. (2017) studied three successful already implemented IoT solutions in machinery companies. The previous authors used criteria described in section 2.2.2 (IoT applications enabling new value proposition to PSS), which

included the selection of smart capabilities and searching for embedded functionalities. The Rymaszewska et al. (2017) study had a similar focus of the study of Zancul et al. (2016, p. 306), related to machinery companies with smart capabilities of product monitoring and control. However, Rymaszewska et al. (2017) did not present any method or tool that the companies would have used to identify the potential IoT solutions, thus not presenting insights to answer the question 1.

Shih, Lee and Huarng (2016) proposed a method to evaluate value creation to PSS of alternative concepts of IoT solutions. The previous authors' proposed method's steps 1 and 2 can present insights to answer question 1, as follow:

- "Step 1. Find customers' unmet needs or dissatisfaction";
- "Step 2. Identify candidate objects as "pseudo actors" and the potential use of IoT technologies";

As discussed in section 2.3.3 (Framework for PSS Design comprising Business Model Design), this research is part of the "PSS Transition Framework," and this research proposed method step 1 shall initiate during the Value Proposition Phase. The Design Thinking (DT) methodology adapted the Bootcamp Bootleg methodology used in the "Value Proposition" phase of the "PSS Transition Framework" has the same approach of the first two steps of Shih, Lee and Huarng (2016) work (PIERONI et al., 2016, p. 415; PIERONI, 2017, p. 136; PLATTNER, 2010). The main activities performed in the "Value Proposition Phase" of the "PSS Transition Framework" are described below.

1. Understand customers and stakeholders to create empathy and identify issues;
2. Define which issues should be solved as a value of the PSS;
3. Ideate solutions for the PSS;
4. Test the ideas with customers, and improve the best PSS solutions according to customer's feedbacks.

While comparing the insights provided from the references above, the conclusion is that the use of the "as-is" proposed "Value Proposition Stage" of the PSS Transition Framework" described in section 2.3.3 (Framework for PSS Design comprising Business Model Design), will be able to identify the "Main IoT Function" that

represents the input for the method's step 1. Furthermore, the ideation solutions should be done by identifying the issues that would be better solved by an automated IoT function, comprising the three attributes of the IoT Representation Card (Artifact 1). It is important to notice that a team of IoT experts should be involved in the ideation of solutions for the PSS, to reach the full range of smart product types depicted in Figure 9 – .

The Main IoT Function identified by the "Value Proposition Stage" of the PSS Transition Framework mentioned above, represents the input for the "method's step 1"

4.3.4.1 Method's Step 1: Detail the main IoT function(s) identified by the Value Proposition Phase of the "PSS Transition Framework."

This present research was developed in the context of the methodology proposed by the "PSS Transition Framework" described by Pieroni et al. (2016, p. 413). However, there is no activity considering the detailing of identified solutions either in the Value Proposition Phase or the Initial Business Model Phase of the "PSS Transition Framework."

Therefore, the method's step 1 uses the following artifacts described in section 4.3 (Method's artifacts) to detail the main IoT function(s) identified by the Value Proposition Phase of the "PSS Transition Framework."

Artifacts to be used:

"Artifact 1 – IoT Representation Card" that emerged from the discussion in section 4.3.1 (Representation of the IoT's object), depicted in Figure 25 and in Appendix A, fulfilled the need to find an IoT's object representation able to describe the most important characteristics of an IoT application, without using deep technical language hard to be used by the PSS Design stakeholders. Therefore it is used in the method's step 1.

"Artifact 2 – eEPC Constructs to detail the IoT Representation Card" that emerged from the discussion in section 4.3.2, depicted in Figure 27 and at Appendix A, fulfilled the need to identify a modeling language and tool to support the IoT functionality detailing, taking into account the IoT's object representation characteristics. Therefore it is used in the method's step 1.

As described in the previous section, the Main IoT Function identified by the “Value Proposition Stage” of the “PSS Transition Framework,” represents the input for the “method’s step 1”, but it can be object of a function breakdown as depicted in Figure 26 . Thus, the defined method’s 1 sequence of tasks are described below:

Tasks:

1. To perform the main IoT function breakdown if necessary using the ARPO eEPC modeling tool;
2. To use the ARPO eEPC modeling tool to generate the Artifact 2, related to each IoT function of the last level of the main IoT function breakdown, described in task 1;
3. To use the information generated in task 2 to generate the respective Artifact 1.

Besides the input, used artifacts and sequence of tasks, there is a need to identify the outcome of each step, as well the skill of participants and the expected period to perform each step.

Participants skills: The designers that perform the methods should have IoT expertise

Expected duration: One to three working days

Expected result: The last level of breakdown of the main IoT function (input), including its IoT Representation Cards and related EPC modeling constructs.

4.3.4.2 Method’s Step 2: Verify the detailed IoT solution within the stakeholders

The “PSS Transition Framework” Value Proposition Phase indicates that the detailed solutions must be tested by the stakeholders. Therefore, the “method’s step 2” is described below.

Input: The IoT Representation Cards (Artifact 1) and its related EPC modeling constructs (Artifact 2) that resulted from “method’s step 1”.

Artifacts to be used:

- The “PSS Transition Framework” Value Proposition Phase tools and methods

Tasks:

1. Each IoT Representation Card along with its related eEPC modeling constructs will be presented and discussed with the stakeholders;

2. The group of stakeholders identifies if there is a need for more information regarding any aspect that emerged from the “method’s Step 1”;
3. If any need for more detailed information is identified, the “method’s Step 1” must be performed again to fulfill the identified request for information

Participants:

PSS Business Model Designers; IoT experts; Company staff responsible for Customer Segments and Relationship; Company staff responsible for Partnerships; Company staff responsible for the offering value proposition to the market; Customer representative.

Period:

Four hours with a coffee break after the first two hours meeting

Expected result: The verification of the IoT Representation Cards and its related EPC Modeling constructs that resulted as outcomes of the “method’s step 1”

4.3.4.3 Method’s Step 3: To add the detailed IoT Representation information to each one of the defined Dimensions of the Initial Business Model

This step is directly related to the requirement 3 of the proposed method, described in section 4.2, which states the need to define questions that will help designers to focus on relating the detailed information resulted from the IoT’s object representation and its group of modeling constructs to an IoT related subset dimensions of the PSS Business Model.

Therefore, this research proposed “method’s step3” is described below.

Input: The verified IoT Representation Cards and its related EPC modeling constructs that resulted from “method’s step 2”.

Artifacts to be used:

- The Questions to relate the IoT Representation detailed information to the Business Model Dimensions (Artifact 3), depicted in Table 12 and Appendix A

Tasks:

1. For each defined Dimension of the Business Model it is applied a question defined in Artifact 3;

2. For each question applied to each dimension of the Business Model, the IoT Representation Card and its related eEPC group of modeling constructs must be considered to add information to the Business Model.

3. Participants:

PSS Business Model Designers; IoT experts; Company staff responsible for Customer Segments and Relationship; Company staff responsible for Partnerships; Company staff responsible for the offering value proposition to the market; Customer representative.

4. Period:

Four hours with a coffee break after the first two hours meeting

Expected result:

The defined dimensions fulfilled with the IoT Representation detailed information, thus defining a new PSS Business Model Scenario, able to support the designer with useful information to be used in the next phases of the PSS Transition Framework.

A summary of the five method's Artifacts generated in this section is presented in Appendix A.

4.4 Overview of the method

In this section, the "Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)" is consolidated using its artifacts below and described in Appendix A.

- Artifact 1: IoT Representation Card
- Artifact 2: eEPC Constructs to detail the IoT Representation Card
- Artifact 3: Questions to relate the IoT Representation detailed information to the Business Model Dimensions
- Artifact 4: Sequence of steps for applying the method

The "Method to support the representation of IoT solutions during the PSS Business Model Design" comprises 3 steps described below. The relation between the artifacts is depicted in Figure 28. The method's steps are supposed to be performed sequentially and are depicted in Figure 29.

The input for the method is provided by the Value Proposition Phase, and the output of the method is represented by an Initial Business Model scenario comprising much more detailed information regarding the identified IoT Function. This method's output will be used as an input for the Business Case Phase. The Value Proposition and Initial Business Model of the "PSS Transition Framework" are described in section 2.3.3 (Framework for PSS Design comprising Business Model Design).

Figure 28 – Artifacts relationship

Table 12 – Questions to correlate the IoT Representation Card attributes to the Business Model Dimensions

Business Model Dimensions	Awareness of real-world events	Intelligence of core applications	Interaction with user
Customer Segments	-	Will the proposed level of intelligence of core applications enable a new customer segment?	Will the proposed level of interaction with the user enable a new customer segment?
Value Proposition	-	Which values are addressed by the proposed level of intelligence of core applications?	Which values are addressed by the proposed level of interaction with the user?
Customer Relationships	-	Is the proposed level of intelligence of core applications able to provide automated services?	Are the automated services resulting from the proposed level of interaction with the user able to replace personal assistance?
Partnerships	Which are the partnerships related to the third party solutions, needed to compose the proposed level of real-world events awareness?	Which are the partnerships related to the third party solutions, needed to compose the proposed level of intelligence of core applications?	Which are the partnerships, related to the third party solutions needed to compose the proposed level of interaction with the user?
Resources	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of real-world events awareness?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of intelligence of core applications?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of interaction with the user?
Revenue	-	Will the proposed level of intelligence of core applications enable new revenue streams?	Will the proposed level of interaction with user enable new revenue streams based on the fulfillment of uncovered needs?
Costs	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of real-world events awareness?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of intelligence of core applications?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of interaction with the user?

Artifact 3

Questions to relate the IoT Representation detailed information to the Business Model Dimensions

SOURCE: Created by the author

Figure 29 –Sequence of steps for applying the method (Artifact 4)

SOURCE: Created by the author

4.5 Exploratory Application of the Method

As discussed in section 3.2.3.3, a first exploratory application of the method was made by the research, using a PSS Car Sharing design blueprint provided by Geum and Park (2011, p. 1611), depicted in Figure 13 of this research. The assumption for this exploratory study is that the cars provided in the PSS Car Sharing, are manufactured by the same company that provides the PSS offering.

The input for the method's Step 1 was represented by the following assumptions:

- During the Value Proposition Phase of the aforementioned PSS Car Sharing example, the stakeholders identified the opportunity to extend the offering of PSS Car Sharing to elder people incapable of driving. However, the company's strategy does not allow contracting drivers because of the labor-intensive liability. Therefore, the utilization of the main IoT Function represented by an "autonomous driverless car" was identified as a solution to attend the identified need;
- It is important to notice that once this solution is implemented, the existing customer segment may also perceive benefits from this potential new value proposition;

Step 1

Detail the main IoT function(s) identified by the Value Proposition Phase of the “PSS Transition Framework.”

Participants:

Researcher

Period:

Three working days

Input: The Main IoT Function “autonomous driverless car.”

Artifacts used:

- The IoT Representation Card depicted in Appendix A (Artifact 1) as the last level of the main IoT function breakdown;
- The eEPC Constructs to detail the IoT Representation Card depicted in Appendix A (Artifact 2)
- ARPO eEPC modeling tool

Tasks Description:

- The main IoT Function was the object of a first level function breakdown that generated three “first level” IoT Functions, as depicted in Figure 30.
- Each one of these three “first level of IoT function breakdown” was detailed to generates the detailed eEPC modeling constructs (Artifact 2) and respective IoT Representation Card (Artifact 1).

The Main IoT Function breakdown presented two eEPC constructs that are common to the detailing of each one of the IoT Function level 1 identified, as depicted in Figure 30 and described below.

- Normative: Traffic regulations

Description: Define the regulations that are mandatory to avoid penalty

- Policy: Government permission to autonomous car driving;

Description: Authorize the offering.

Figure 30 – Main IoT Function breakdown – eEPC constructs of IoT Function level1

SOURCE: Created by the author

The eEPC modeling constructs of IoT Function “Drive to any address avoiding collision” were generated and depicted in Figure 31. The IoT Representation Card 1 was then consolidated and depicted in Figure 32.

Figure 31 – (Drive to any address avoiding collision) eEPC modeling constructs

SOURCE: Created by the author

Figure 32 – IoT Representation Card 1 – Drive to any address avoiding collision

SOURCE: Created by the author

After detailing the IoT Function “Drive to any address avoiding collision,” the eEPC modeling constructs of IoT Function “Drive obeying traffic signs and rules” were generated and depicted in Figure 33. The IoT Representation Card 2 was then consolidated and depicted in Figure 34.

Figure 33 – (Obey Traffic Signs and Rules) eEPC modeling constructs

SOURCE: Created by the author

Figure 34 – IoT Representation Card 2 – Obey Traffic Signs and Rules

SOURCE: Created by the author

After detailing the IoT Function “Obey Traffic Signs and rules,” the eEPC modeling constructs of IoT Function “Optimize Routing” were generated and depicted in Figure 35. The IoT Representation Card 3 was then consolidated and depicted in Figure 36.

Figure 35 – (Optimize Routing) – eEPC modeling constructs

SOURCE: Created by the author

Figure 36 – IoT Representation Card 3 – Optimize Routing

SOURCE: Created by the author

Step 2

Verify the detailed IoT solution within the stakeholders

Not applicable in the method's exploratory application

Step 3

To add the detailed IoT Representation information to each one of the defined Dimensions of the Initial Business Model

Participants:

Researcher

Period:

Four working hours

Input: The verified IoT Representation Cards and its related eEPC group of modeling constructs

Artifacts used:

- The "Questions to relate the IoT Representation detailed information to the Business Model Dimensions," depicted in Appendix A (Artifact 3)

Tasks Description:

- For each defined Dimension of the Business Model was applied a question related to each attribute of the IoT Representation Card;
- For each question applied to each dimension of the Business Model, the IoT Representation Card description and its related eEPC group of modeling constructs were considered to add information to the Business Model.
- Considering that three IoT Representation Cards and its related eEPC group of modeling constructs were generated during "method's Step 1", the selected Business Dimensions were fulfilled using the three groups of information, each one summing up with the previous, as described below.
 - The information added by IoT Representation Card 1 (Drive to any address avoiding collision), and its related eEPC group of modeling constructs;

- The information added by IoT Representation Card 2 (Obey Traffic Signs and Rules), and its related eEPC group of modeling constructs;
- The information added by IoT Representation Card 3 (Optimize routing), and its related eEPC group of modeling constructs.

In a real application of the method, the IoT Representation detailed information added to each dimension of the PSS Business Model should result from the discussion amongst the stakeholders. The stakeholder's discussion is a key success factor because the information added should not be a simple transcript of the generated eEPS modeling constructs and respective IoT Representation Card. Considering that only the researcher performed the step 3, the reasoning needed to add the detailed IoT representation information to the dimensions of the PSS Business Model was very limited.

The Business Model Dimensions were fulfilled with the consolidated information as described below.

a. Customer Segments

The information added by IoT Function 1: No added information

The information added by IoT Function 2: A new Customer Segment was added: Elder people incapable of driving. This new customer segment was considered strategic for the company, because of the fast growth in life expectancy, as well as the demand for mobility from this new and large segment of the population,

The information added by IoT Function 3: No added information

b. Value Proposition

The information added by IoT Function 1: No added information

The information added by IoT Function 2: To attend the identified need in step 1 (extend the PSS Car Sharing PSS to elder people incapable of driving), while providing a driverless Car Sharing able to drive to any address avoiding collision and obeying traffic signs and rules

While attending the new customer segment, the new added value has potential to extend the utilization rate within the existing customers,

because there will be no need to find a car parked in the street nearby or to pick up the car in a company's agency

The information added by IoT Function 3: To minimize the travel time, and enable the customer possibility to choose the best route

While transforming the customer in passenger by the use of IoT Functions, there is potential to provide new value proposition not directly related to IoT within the existing customers, such as providing video on demand and music on demand

c. Customer Relationship

The information added by IoT Function 1: Provide the customer with a life insurance plan and manage the flow of information regarding the events related to this plan

The information added by IoT Function 2: No added information

The information added by IoT Function 3: No added information

d. Partnerships

The Information added by IoT Function 1: Regardless of the fact that the company already have a partner that provides GPS sensor for car location information (assumption), there is a need to establish new partnerships able to provide the following range of sensors: Lidars Sensors to recognize distant objects; Cameras to recognize near objects; Cameras to recognize customer.

A new partnership with the insurance company will represent a key issue to mitigate the identified risks, related to passenger life insurance and third party both life and property insurance.

There will also be a need to establish a partnership with every City Hall to receive a monthly updated city map, comprising every change in the streets directions; existing streets blocked to repair and so on.

The information added by IoT Function 2: The partnership that provides the cameras to recognize near objects must be able to provide also cameras

able to recognize traffic signs with a high level of accuracy. Otherwise, a new partnership will be needed

The partnership with every City Hall will have to be upgraded to support the management of City Hall penalties, which may result from events related to the driverless car.

The information added by IoT Function 3: The partnership with every City Hall will have to be upgraded to support the management of City Hall Cameras real-time images of events

There will be a need to establish a partnership with sites that provide real-time speedometer data from every smartphone in the route, consolidating that information on the average speed of every street in the route

e. Resources

The information added by IoT Function 1: There will be a need regarding a new car to be provided to the PSS Car Sharing, with IoT embedded technologies, such as autonomous car driving control capabilities, routing capability, and a display positioning the car in the route while using the third party resources.

There will be a need for a system to manage the continuous City Map information updating.

There will be a need for a system to manage the passenger insurance plans events.

There will be a need for a system to manage the third party insurance plans events

The information added by IoT Function 2: There will be a need for an upgraded car driving capability, and a speed limit threshold display (internal)

There will be a need for a system to manage the City Hall penalties events

The information added by IoT Function 3: There will be a need for a system to manage the information regarding traffic events provided by City Hall cameras

There will be a need for a system to manage the information regarding the average speed of every street in the route

There will be a need of interactive display providing alternative routes information

f. Revenue

The information added by IoT Function 1: No added information

The information added by IoT Function 2: While adding a new and large customer segment, the recurrent “pay per use” revenues are expected to presents a significant growth.

The utilization rate of a driverless car also has potential to grow, because of the convenience represented by a driverless car. Thus, representing a potential growth in the monthly revenue with the same number of cars

The information added by IoT Function 3: No added information

g. Costs

The information added by IoT Function 1: New cost structure that must take into consideration the cost of both internal and third party resources described in item “e.”

The risks regarding passenger life insurance and third party both life and property insurance will drive new costs to provide life insurance plans provided by new partners. Moreover, even considering the insurance plans being provided, the identified risks’ liability must be considered in the company’s balance.

The information added by IoT Function 2: New cost structure that must take into consideration the cost of both internal and third party resources described in item “e” (Round 2)

The risk regarding Citi Hall ticketing resulted from penalties related events, represents a liability that must be considered in the company’s balance.

The information added by IoT Function 3: New cost structure that must take into consideration the cost of both internal and third party resources described in item “e” (Round 3)

Outcome: A PSS Business Model Scenario enriched by the detailed IoT Representation information, related to the identified IoT Functions.

4.6 Evaluation of the Method with a Focus Group

The consolidation of the method's artifacts and the result of the exploratory application of the method were presented to a focus group of experts, to perform an initial demonstration of the utility of the method by a Confirmatory Focus Group (CFG) (TREMBLAY; HEVNER; BERNDT, 2010, p. 602). The structure of the focus group and the questioning route were described in section 4.6.1, and the results of the Focus Group Open Discussion are described in section 4.6.2.

4.6.1 Focus Group Structure and Questioning Route

The Focus Group questioning route initiated with an explanation of the context in which the method's development is inserted, a detailed description of each element used by the method, its application plan, and a detailed description of the exploratory application of the method and its results.

Focus Group Structure

Moderator: Researcher

Participants:

- Two PSS Design experts
- One Circular Economy expert;
- Three Industry 4.0 experts, one of them with expertise in IoT solutions and General Manager of a Robotics Lab;
- Two shareholders of a Technology Startup with an offering of Drones for Precision Agriculture;
- One Project Management (agile and hybrid) expert
- One Sustainability and Maturity Models expert

Evaluation Tasks

Task1: to present the context where the method is inserted

Duration: 15 minutes of presentation and 5 minutes to answer doubts

Task 2: to present the 3 artifacts used in the method

Duration: 5 minutes of presentation and 5 minutes to answer doubts from the participants for each artifact (total 30 minutes), to leverage the understanding;

Task 3: to present the first step of the method as well as its Application Plan

Duration: 10 minutes of presentation

Task 4: to present the first step of the exploratory Application of the method

Duration: 10 minutes of presentation and 10 minutes to answer doubts from the participants

Task 5: to present the second step of the method as well as its Application Plan

Duration: 5 minutes of presentation

Task 6: to present the third step of the method as well as its Application Plan

Duration: 5 minutes of presentation

Task 7: to present the third step of the exploratory Application of the method

Duration: 10 minutes of presentation and 10 minutes to answer doubts from the participants

Discussion: eight questions were presented to the Focus Group open discussion, with 15 minutes of discussion per question. The questions presented were:

- 1- How easy the method is to understand?
- 2- How much of IoT and PSS knowledge is needed to perform the method?
- 3- Is the step-to-step of the method logic?
- 4- What were the greatest difficulties that you identified, to understand and apply the method?
- 5- Do you think that the method covers all possible dimensions of a Business Model comprising IoT Solutions?
- 6- Based on the exploratory application, is the method capable of generating detailed information related to the IoT solution to the Business Model Design?
- 7- What were the greatest advantages/benefits of the method that you identified?
- 8- Is the Business Model scenario generated by the method able to help stakeholders to evaluate new value proposition from IoT solutions?

4.6.2 Results of Focus Group Open Discussion

The focus group open discussion that occurred during one-hour and twenty-two minutes was recorded, after that, the researcher analyzed all the voice recorded content. The consolidation of the method's evaluation that emerged from the discussion amongst the participants as well as samples of the participant's comments is described below, following the sequence of the questioning route described in section 4.6.1.

1- How easy the method is to understand?

In general, there were consensuses amongst the participants that the method is easy to understand, but with important remarks regarding the PSS and IoT minimum knowledge needed, which was discussed in question 2. The shareholder of a Technology of a Startup declared: "I just had the overall understanding from the middle to the finish of the explanation, because there are several supporting artifacts and linked step's activities, but now I think that I can apply the method." The general manager of a Robotic's Lab declared: "I think that the method seems to be intuitive."

Regardless the remarks related to the PSS and IoT minimum knowledge required to understand the method, the need for a minimum knowledge related to modeling languages such as eEPC was considered important. An expert in Circular Economy emphasized: "The method seems to solve an important problem, but I would not be able to perform the method's step 1 (Detail the main IoT function), in special regarding the generation of the eEPC modeling constructs". At this point, the moderator clarified that "IoT experts" was the skill required to perform this step 1.

However, the participants emphasized the need for a minimum knowledge regarding modeling languages, in special related to the used eEPC modeling language and the defined set of modeling constructs. Therefore, an important suggestion that emerged from the discussion was to elaborate focused training within the stakeholders before applying the method, to enable the design team to use better the common language proposed by the method.

2- How much of IoT and PSS knowledge is needed to perform the method?

During this discussion several aspects emerged related to the IoT needed knowledge to perform the method's step 1 (Detail the main IoT function), which is one

assumption declared in the method's application plan, described in section 4.3.4 (Sequence of steps for applying the method).

The most important issue discussed was related to the level of IoT expertise needed, because there were consensuses amongst the participants that the level of IoT expertise needed to perform the step 1 should not be too deep. The general manager of a Robotic's Lab emphasized: "If the profile of the designer that develops step 1 (Detail the main IoT function) is too technical, he would prefer to use a more technical modeling language". In that sense, the same participant suggested considering aa expertise for the designer of step 1, more related to an experienced "system engineer" with good but less technical knowledge regarding IoT, also mixed with business knowledge.

Another possible solution to solve this identified issue was proposed by one of the PSS Design experts as follow: "To involve a group of different designers with different knowledge about IoT and Business instead of looking for a rare knowledge to perform the task." This suggestion was agreed upon by all the participants; in special by the Project Management (agile and hybrid approaches) expert.

Regarding the PSS knowledge, there was a common understanding amongst the participants that just a more high-level understanding of PSS was needed to apply the method. The reason for this conclusion is related to the fact that the method's designers would be adding information related to IoT, jointly with the other PSS designers that participate in the overall PSS Business Model Design.

However, one of the shareholders of the technology startup disagreed by declaring that: "PSS knowledge is also important because several aspects regarding providing services should be considered while developing the method." On the other hand, one of the PSS Design experts declared that: "Initially it will be just needed a general knowledge regarding PSS because the issues related to PSS will emerge naturally along the design of the PSS Business Model of the PSS Transition Framework."

3- Is the step-to-step of the method logic?

In general, there were consensuses amongst the participants that the method's step-to-step is logical, but the period expected for each step will depend on the knowledge and experience of the design team.

Another important remark was related to the order to apply the Artifact 1 (IoT Representation Card) and Artifact 2 (eEPC Constructs to detail the IoT Representation Card). The Project Management expert quoted: “I was in doubt if the artifact 1 should be used before or after the Artifact 2, because it seems to be a consolidation of information. Therefore, the Artifact 2 should be used before artifact 1. At this point, the moderator clarified that there is no restriction, regarding the order of use of Supporting Artifacts 1 and 2 at method’s step 1 (Detail the main IoT function).

One of the PSS design experts declared that “while designing a PSS in an initial phase the artifact 1 could be used as a first step to be detailed further, and the general manager of a Robotic’s Lab agreed with this approach. Moreover, the Circular Economy expert and the Project Management added that the IoT Representation Card (Artifact 1) could represent the role of the “agile product vision”, described by Benassi et al. (2016, p. 211) as being able to “challenge the team in its search for innovative solutions”.

4- What were the greatest difficulties that you identified, to understand and apply the method?

Considering that most of the participants agreed that the method should be applied to different moments of the PSS Transition Framework, one important challenge to face during the development of method’s step 1 (Detail the main IoT function), is related to the level of description of the modeling constructs for each moment that the method is applied. The focus group agreed that regardless of applying the method in the Initial Business Model it could also be applied in a posterior Refined Business Model, or even at the ICT Architecture phase.

The challenge mentioned above is directly related to the use of the Artifact 2 (eEPC Constructs to detail the IoT Representation Card). In this detailing task, the designer should be aware of how much information should be detailed, depending on the moment of application of the method as described above.

Another important difficulty pointed by the focus group is related to the discussion of question 2 above (How much of IoT and PSS knowledge is needed to perform the method?). The general manager of a Robotic’s Lab proposed that: “It is necessary a profile of a systems engineer with both technical and business experience.” Other members of the focus group propose a multidisciplinary team. Therefore, this level of

detail of the result from the method's step 1, represents a difficulty to understand and apply the method according to the focus group participants.

The need for a minimum common understanding related to modeling languages was also emphasized, as discussed in question 1 (How easy the method is to understand?). One Industry 4.0 expert declared that: "there is a need for modeling constructs minimum knowledge to understand the generated detailed information." Therefore, this aspect should be considered in focused training to the designer's team, before applying the method.

5- Do you think that the method covers all possible dimensions of a Business Model comprising IoT Solutions?

The focus group developed an important discussion regarding the set of the used Business Dimensions. One PSS Design expert asked why all the 11 Business Model Dimensions of the "PSS Transition Framework" were not considered, and at this point, the moderator clarified that the seven used dimensions were a subset of the eleven dimensions mentioned, as well a subset of the Canvas Business Model.

Other participants had different opinions, such as the Circular Economy expert that declared: "I felt much more comfortable while using the standard Business Model dimensions." The General Manager of a Robotic's lab declared that: "I agree with the idea of using a subset of dimensions more related to IoT, to achieve efficiency in the process of design." The Project Management (agile and hybrid) also emphasized that: "No problem to use a subset of Business Model Dimensions, based on the explanation of how this subset was generated."

6- Based on the exploratory application, is the method capable of generating detailed information related to the IoT solution to the Business Model Design?

In general, the focus group agreed that the method could be applied from the Initial Business Model, a posterior Refined Business Model generated by other iterations, or even at the ICT Architecture phase, as discussed in question 4 (What were the greatest difficulties that you identified, to understand and apply the method?). During the discussion of question 4 the focus was related to the challenge represented by the identification of the right level of detail, which should be applied in each phase of the "PSS Transition Framework."

One of the PSS Design experts emphasized that: “the method generates so much information that should be used in the refinement of the Initial Business Model during the ICT Architecture phase, instead of being used in the Initial Business Model.” Another contribution came from Project Management (agile and hybrid approaches) expert, which emphasized that “the method should be used in different iterations, considering that the IoT knowledge needed must be improved for each iteration”.

During the discussion of question 6 it was emphasized again by many participants that the Artifact 1 (IoT Representation Card) can be used, even when considering a modeling language different from the eEPC extended view, which was defined as an element of the method. Moreover, one of the Industry 4.0 experts asked: “Why the eEPC was chosen as the modeling language used by the method?” At this point, the moderator clarified that the eEPC extended view was chosen because the PSS integrates products and services and that the focus of the research was to add information to the Business Model Design, thus not being focusing on describing the more technical functionality of the products. The eEPC extended view comprises modeling constructs able to describe resources that emerge from both product and services, and able also to describe other information such as policies, regulations, and risks.

7- What were the greatest advantages/benefits of the method that you identified?

In general, there were consensuses amongst the participants that the method represents an important contribution regarding the capability to provide a common language to represent IoT Solutions within a PSS Business Model Design.

Another contribution mentioned was the flexibility of the method to provide detailed information, related to the IoT Representation of an identified main IoT function in different phases of the “PSS Transition Framework.” The Circular Economy expert emphasized: “The method’s greatest contribution is to establish a common space for a multidisciplinary team of designers, which is needed for the design of a PSS Business Model comprising IoT solutions.”

One of the Technology Startup’s shareholders added that: “In the case of startups the method will be very useful to anticipate important information regarding the IoT solutions to the PSS Business Model Design.” The General Manager of a Robotic’s

lab also emphasized that: “the information provided by the method comprises an intermediate degree of abstraction that all the stakeholders can share.”

8- Is the Business Model scenario generated by the method able to help stakeholders to evaluate new value proposition from IoT solutions?

In general, there were consensuses amongst the participants that the method can help the multidisciplinary team to evaluate if an IoT solution can result in a new value proposition to PSS while adding relevant and detailed information regarding IoT during the PSS Business Model Design. One of the Technology Startup shareholders declared that: “The method generates a lot of information and brings more realism to the dimensions of the Business Model.”

Finally one of shareholders of the technology startup emphasized that the method represents an important less technical common language, to design a Business Model for startups that includes IoT solutions in the offering, and declaring that: “the method provides a common language better to anticipate important information, without using a too technical modeling language such as XML”.

5 Final considerations

The final considerations represent the concluding remarks of this research. This chapter is organized into two sections described below.

- Section 5.1 summarizes the main insights regarding this research objective and obtained results, comprising as well the expected contributions for theory and practice;
- Section 5.2 described the identified limitations of this research and the future research opportunities.

5.1 Insights and contributions

An important insight from this research is that Business Model Design should be used to relate the potential of an IoT solution with the company's Business Model. This approach is critical to capture value inside a corporation because the IoT bundle of different technologies can affect several dimensions of a PSS Business Model. However, a more specific and detailed representation of an IoT object is needed, to address that issue.

The Business Model Innovation can represent an important factor to improve the adoption of PSS Business Model, while increasing differentiation against competition related to the business strategy to be adopted, and the use of technologies and services able to enhance the value delivered to the customer, making it hard to be replicated by competition (TEECE, 2010, p. 173). Even considering that the "as is" PSS Business Model represents an innovation itself, the IoT solutions may enable new value proposition to PSS while providing Business Model innovation, because the new Business Models based on IoT almost often change or even replace an existing Business approach (BUCHERER; UCKELMANN, 2011, p. 259).

Another insight from this research is that besides providing innovation from its technologies, the IoT's object role of "pseudo actor" can affect several dimensions of a PSS Business Mode, and because of that there is a need to provide detailed and specific IoT information during the PSS Business Model Design, which can address that issue.

The main contribution that emerged from this research is the proposition of a method able to provide much more detailed information regarding an IoT solution, based on a

common language that resulted from the use of an abstraction of an IoT object, during the PSS Business Model Design. The method integrates important approaches that were not found together in the literature, as follow:

- To use the Value Proposition Phase of the “PSS Transition Framework” to identify needs, opportunities and shortfalls, with potential to be solved by an automated IoT function. The outcome of the Value Proposition Phase will represent the input for the “Method to represent IoT solutions during the Business Model Design of a Product-Service System (PSS)”;
- To use an IoT Function representation able to describes every kind of IoT function, from monitoring and control to optimization and autonomy, while providing a common intermediate language that can be easily shared by a multidisciplinary group of stakeholders;
- To detail the potential main IoT function identified by the Value Proposition Phase, using the defined IoT Representation and the related eEPC constructs, to provide much more information to the stakeholders, rather than the plain text high-level descriptions found in the literature related to IoT application into PSS design;
- To use the detailed information that results from the defined IoT Representation attributes, levels, and its related eEPC constructs, to add specific and detailed IoT related information to the dimensions of a PSS Business Model.

While answering the research question (How to represent the IoT characteristics in detailing a PSS Business Model according to the “PSS Transition Framework”?), the result of the method’s initial demonstration of the utility by Focus Group described in section 4.6.2 (Results of Focus Group Open Discussion), reached a consensus:

- The integration of the approaches described above represents an important contribution to PSS Business Model Design that comprises IoT solutions. The method provides detailed and relevant information to be used not just in an Initial Business Model, but also in several possible iterations along the next phases of the “PSS Transition Framework”, while using a common language

able to be shared by the stakeholders during the PSS Business Model Design.

One important aspect considered in this research was to anticipate more detailed information related to the application of IoT in the early stages of PSS design. This aspect must be emphasized because, according to the literature, the main IoT technologies such as ICT (Information and Communication Technology) and Network of Sensors must always be considered jointly. This IoT characteristic represents a challenge to PSS Design, regarding the gathering of enough information to help the evaluation of a specific IoT Function capacity, to enable new value proposition to PSS. For instance, the more detailed information regarding different aspects of the proposed IoT function, more likely potential risks will be identified in the early stage of PSS Design, as well as more information regarding new needed resources, partnerships and related costs will be provided earlier.

The exploratory application of the method and the discussion that emerged from the Confirmatory Focus Group (CFG) in section 4.6.2 (Results of Focus Group Open Discussion), were able to provide useful insights that were used to identify the method's contribution to theory and designers, described below.

Contribution to theory

The main contribution to the theory was to integrate different approaches that emerged from different bodies of knowledge. The IoT related literature is very focused on very detailed technical aspects of IoT objects, such as communication stacks standards, service-oriented architecture (SOA), modeling languages such as XML, and types of sensors. On the other hand, PSS design literature is very focused on different methodologies related to the joint development of product and services, with little focus on the Business Development Design of IoT solutions, generally using a high-level description in an open textual format regarding the IoT solution. The artifacts produced during the method elaboration represented ways to address the integration of these two different bodies of knowledge.

The Artifact 1 (IoT Representation Card) and related detailed eEPC modeling constructs (Artifact 2) can represent an IoT function in a way that can be more easily shared by a multidisciplinary team. This condition is enabled by an intermediate level of abstraction, between a technical and a business approach, used to describes the

IoT solution. Moreover, the defined IoT Representation with its eEPC modeling constructs anticipates specific values, resources, partnerships and liabilities related to a specific IoT solution, to the early stages of a PSS Design.

As a result of the Focus Group discussion described in section 4.6.2, the Artifact 1 (IoT Representation Card) has the potential to be used as a first “agile product vision” for an initial PSS Business Model Design comprising IoT, could represents the role of the “agile product vision”, thus being able to “challenge the team in its search for innovative solutions” (BENASSI; AMARAL; FERREIRA, 2016, p. 211).

The Artifact 3 (Questions to relate the IoT Representation detailed information to the Business Model Dimensions), provides insights regarding the most important PSS Business Model Dimensions, to be considered while evaluating IoT functions, and suggest questions to address each one of the IoT Representation attributes. Thus, keeping the focus on the IoT Representation’s detailed information.

Finally, the anticipation of much more IoT detailed information into the PSS Business Model Design, presents potential to represent innovation while adding a more comprehensive and deeper level of information for each defined dimension of the PSS Business Model, thus presenting potential to change or even replace an existing Business approach (BUCHERER; UCKELMANN, 2011, p. 259).

Contribution to PSS designers

The method contributes to PSS designers while providing a detailed and flexible IoT Function representation, able to add a great amount of information to the PSS Business Model Dimensions most often used by IoT offering. The method’s outcome is represented by a comprehensive set of detailed and specific IoT related information, which will be added into each defined PSS Business Model Dimension.

The method creates a common language for designers with different knowledge background. On the one hand, the proposed IoT representation is not based in technical constructs, and on the other hand, it generates modeling constructs comprising much more information, rather than a plain free textual description of the IoT function. The benefits regarding the common language for designers represented by the IoT Representation and its related modeling constructs were emphasized as a consensus by the focus group discussion, described in section 4.6.2.

The detailed information provided in the method's Step 1 (Detail the main IoT function(s)), described in Appendix A - Artifact 4, regarding the IoT Representation Cards and its related eEPC modeling constructs, enables designers to identify in advance new needed partnerships and resources, which are related to the specific IoT technologies involved. The identified needed resources will add relevant new issues related to the cost structure of the PSS offering. Moreover, the information provided by step 1 might enable the designer to anticipate risks linked to technical, managerial and liabilities issues, which would be hardly identified in the early stages of the PSS Design, if the most often used free textual description of an IoT function was used. This benefit to designers was also confirmed by the focus group discussion, described in section 4.6.2, especially when applying the method to startups.

Finally, the anticipation of much more IoT detailed information into the PSS Business Model Design could help the designers in the evaluation of a potentially new value proposition that may result from the Business Model Scenario created by the method. As discussed in section 4.6.2 (Results of Focus Group Open Discussion), question 8, the method can "generates a lot of information and more realism to the Business Model."

5.2 Limitations and future research opportunities

The limitations regarding the research methodology are described below:

- The small number of references found in the literature with successful IoT implementations into PSS Business Model, to be used in the cross-case comparisons described in section 3.2.3.2 (PS Activity 2 – Development of the method's artifacts);
- The exploratory application of the proposed method was made only by the researcher that tried to have the participation of more IoT experts. However, this ideal situation was difficult to reach, because the need of at least a three day commitment not possible to perform at least on exploratory focus group (EFG) to "achieve rapid incremental improvements in artifact design" (TREMBLAY; HEVNER; BERNDT, 2010, p. 602). The reason was that it was not possible to found companies able to involve a team of skilled designers, for two or three days that is the minimum period required to perform a real

case study with the focus group applying the method. It was not possible to perform at least on exploratory focus group (EFG) to “achieve rapid incremental improvements in artifact design” (TREMBLAY; HEVNER; BERNDT, 2010, p. 602). The reason was that it was not possible to find companies able to involve a team of skilled designers, for two or three days that is the minimum period required to perform a real case study with the focus group applying the method.

The limitations regarding the theory are described below:

- The small number of references found in the literature regarding PSS Design methodologies that encompass Business Model Design;
- The small number of references found regarding the design of IoT offering while evaluating the outcome in the company's Business Model;
- The small number of references found in the literature with successful IoT implementations into PSS Business Model.

The future research opportunities are described below:

- The method should be applied in real case studies to identify opportunities for improvement;
- There is an opportunity for future research to use the method's outcomes to evolve in the next steps of the PSS Transition Framework. For instance, to identify how the IoT application into PSS will impact the Business Case phase while involving a large number of new assets in the field and third-party software in cloud architecture;
- The method generates a great amount of useful information about the dimensions of a PSS Business Model. In that sense, the method could help the stakeholders to evaluate new value proposition enabled by IoT into PSS,
- Another opportunity for future research is to use iterations of the method as suggested by the focus group discussions, in other phases of the “PSS Transition Framework” such as the Business Process Architecture, and the ICT Architecture.

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Appendix A – Summary of the Method's Artifacts

Artifact 1: IoT Representation Card

Figure 25 – IoT Representation Card

SOURCE: Created by the author

Attributes' levels Description

- Awareness of real-world events: Level 1 = Single sensing, corresponding to plain activities; Level 2 = Multiple sensing intra-system, corresponding to domain-specific policies; Level 3 = Multiple sensing inter-systems, corresponding to work processes
- Intelligence of core applications: Level 1 = Aggregation of information, corresponding to single records of related information; Level 2 = Rules based model, corresponding to applications based on rules; Level 3 = Workflows based model, corresponding to applications based on workflows
- Interaction with user: Level 1 = Status display, corresponding to simple display of information; Level 2 = Thresholds warnings, corresponding to alarms related to pre-defined thresholds; Level 3 = User work guidance, corresponding to the user activities being guided by an autonomous IoT object

Artifact 2: eEPC Constructs to detail the IoT Representation Card

The eEPC modeling tool ARPO is used by this research to enable a graphic representation of the IoT function breakdown. The first level is represented by a high level main function free textual description, and the last level is represented by the IoT's Representation Card, and its related eEPC Modeling constructs, described below.

Figure 27 – eEPC Constructs to detail the IoT Representation Card (Artifact 2)

Source: Created by the author

Modeling constructs Description

- Function: describe the activities that comprise the IoT function being detailed;
- Event: outcome of the eEPC modeling constructs related to an IoT Representation Card (Artifact 1)
- Normative: to describe company, partners and government definitions, which represent restrictions that must be considered by the IoT function;

- Policy: to describe both private or government regulations that must be addressed by the IoT function;
- Product: to describe resources provided by both the company and partners' products, which are needed to support the IoT function being detailed;
- Service: to describe resources provided by both the company and partners' services, which are needed to support the IoT function being detailed;
- System: to describe resources provided by both the company's and partners' systems, which are needed to support the IoT function being detailed;
- Risk: to highlight the critical risks that may emerge from the application of the IoT function being detailed.
- IoT's Object Attribute: A new construct was created to represent each attribute of the IoT Representation Card (Artifact 1) presented in section 4.3.1.

Artifact 3: Questions to relate the IoT Representation detailed information to the Business Model Dimensions

The artifact is represented by Table 12, which uses a set of questions to relates the detailed information regarding the IoT Representation Card, to the IoT's most used Business Model Dimensions.

Table 12 – Questions to relate the IoT Representation Card attributes to the Business Model Dimensions

Business Model Dimensions	Awareness of real-world events	Intelligence of core applications	Interaction with user
Customer Segments	-	Will the proposed level of intelligence of core applications enable a new customer segment?	Will the proposed level of interaction with the user enable a new customer segment?
Value Proposition	-	Which values are addressed by the proposed level of intelligence of core applications?	Which values are addressed by the proposed level of interaction with the user?
Customer Relationships	-	Is the proposed level of intelligence of core applications able to provide automated services?	Are the automated services resulting from the proposed level of interaction with the user able to replace personal assistance?
Partnerships	Which are the partnerships related to the third party solutions, needed to compose the proposed level of real-world events awareness?	Which are the partnerships related to the third party solutions, needed to compose the proposed level of intelligence of core applications?	Which are the partnerships, related to the third party solutions needed to compose the proposed level of interaction with the user?
Resources	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of real-world events awareness?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of intelligence of core applications?	Which are the internal and external resources regarding product, services, and systems, needed to be used by the proposed level of interaction with the user?
Revenue	-	Will the proposed level of intelligence of core applications enable new revenue streams?	Will the proposed level of interaction with user enable new revenue streams based on the fulfillment of uncovered needs?
Costs	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of real-world events awareness?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of intelligence of core applications?	Which kind of cost structure will be defined considering the new partnership environment, needed to compose the proposed level of interaction with the user?

SOURCE: Created by the author

Artifact 4: Sequence of steps for applying the method

Step 1

Detail the main IoT function(s) identified by the Value Proposition Phase of the “PSS Transition Framework.”

Participants:

IoT experts

Period:

One to three working days

Input: The Main IoT Function identified by the Value Proposition Phase of the “PSS Transition Framework.”

Artifacts to be used:

“Artifact 1 – IoT Representation Card”, which emerged from the discussion in section 4.3.1), depicted in Figure 25 and in Appendix A , fulfilled the need to find an IoT’s object representation able to describe the most important characteristics of an IoT application, without using deep technical language hard to be used by the PSS Design stakeholders. Therefore it is used in the method’s step 1.

“Artifact 2 – eEPC Constructs to detail the IoT Representation Card”, which emerged from the discussion in section 4.3.2, depicted in Figure 25 and in Appendix A, fulfilled the need to identify a modeling language and tool to support the IoT functionality detailing, taking into account the IoT’s object representation characteristics.. Therefore it is used in the method’s step 1.

Tasks:

1. To perform the main IoT function breakdown if necessary using the ARPO eEPC modeling tool;
2. To use the ARPO eEPC modeling tool to generate the Artifact 2, related to each IoT function of the last level of the main IoT function breakdown, described in task 1;
3. To use the information generated in task 2 to generate the respective Artifact 1.

Expected result: The last level of breakdown of the main IoT function (input), including its IoT Representation Cards and related EPC modeling constructs.

Step 2

Verify the detailed IoT solution within the stakeholders

Input: The IoT Representation Cards (Artifact 1) and its related EPC modeling constructs (Artifact 2) that resulted from “method’s step 1”.

Participants:

PSS Business Model Designers; IoT experts; Company staff responsible for Customer Segments and Relationship; Company staff responsible for Partnerships; Company staff responsible for the offering value proposition to the market; Customer representative.

Period:

Four hours with a coffee break after the first two hours meeting

Artifacts to be used:

- The “PSS Transition Framework” Value Proposition Phase tools and methods

Tasks:

1. Each IoT Representation Card along with its related eEPC modeling constructs will be presented and discussed with the stakeholders;
2. The group of stakeholders identifies if there is a need for more information regarding any aspect that emerged from the “method’s Step 1”;
3. If any need for more detailed information is identified, the “method’s Step 1” must be performed again to fulfill the identified request for information, as depicted in Figure 29

Expected result: The verification of the IoT Representation Cards and its related EPC Modeling constructs that resulted as outcomes of the “method’s step 1”

Step 3

To add the detailed IoT Representation information to each one of the defined Dimensions of the Initial Business Model

Participants:

PSS Business Model Designers; IoT experts; Company staff responsible for Customer Segments and Relationship; Company staff responsible for Partnerships; Company staff responsible for the offering value proposition to the market; Customer representative.

Period:

Four hours with a coffee break after the first two hours meeting

Input: The verified IoT Representation Cards and its related eEPC group of modeling constructs

Artifacts to be used:

- The questions to relate the IoT Representation Card information to the Business Model Dimensions, depicted in Appendix A; (Artifact 3)

Tasks:

1. For each defined Dimension of the Business Model it is applied a question defined in Artifact 3;
2. For each question applied to each dimension of the Business Model, the IoT Representation Card and its related eEPC group of modeling constructs must be considered to add information to the Business Model.

Expected result: A Business Model Scenario that contains detailed information regarding the IoT Function identified in the Value Proposition Phase of the “PSS Transition Framework”, thus providing the PSS Design Team with useful information to support the evaluation of IoT into PSS Business Model Design.