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Doctoral Degree in Technology Innovation and Management

"Product Service System evolution in the data-driven era: impacts on service offering and engineering"

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List of abbreviations

AI – Artificial Intelligence

API - Application Programming Interface

B2B - Business-to-Business

B2B2C - Business-to-Business-to-Customer

BMS – Building Management System

CB – Circuit breaker

CPS – Cyber-Physical System

DD – Data-Driven

DDPSS – Data-Driven Product Service System

DSSD – Data Structured Systems Development

EDCS – Electrical Distribution Control System

EGE – Energy Expert

EnPI – Energy Performance Indicators

ESCo - Energy Service Company

ICT – Information Communication Technologies

IIoT – Industrial Internet of Things

IoS - Internet of Service

IoT – Internet of Things

IT – Information Technologies

KPI- Key Performance Indicators

LEED - Leadership in Energy and Environmental Design

ML – Machine Learning

NFV- Network function virtualization

OT - Operational Technologies

PF – Power Factor

PLC - Programmable Logic Controller

PSP - Product Service Provider

PSS – Product Service System

RFID – Radio Frequency Identification

R&D – Research and Development

ROI – Return on Investment

SCADA -Supervisory Control and Data Acquisition

SDL – Service-Dominant logic

SCP – Smart Connected Product

SE – Service Engineering

SP – Service Provider

TEEs - Energy Efficiency Titles

WSN – Wireless Sensor Network

EXECUTIVE SUMMARY

The context

In the last decade, two recent macro-phenomena are specifically challenging the manufacturing strategies: Servitization and Digitalization (Frank, Mendes, Ayala, and Ghezzi, 2019). On one side the possibility to face the competition and increase the scope of value creation activities by selling bundles of product and services and on the other side the advancement in the technological domain that enables the development of automatic and intelligent systems and products. By adopting technologies that belong to the Industry 4.0 domain and leveraging synergies that come from both of the two trends, several opportunities are emerging for manufacturers. Specifically, one of the most relevant aspect to be considered is the possibility to retrieve a large amount of data from connected sources that, matched with effective data analytics tools, can become a key source of value creation in the context of service provision. Despite opportunities and some successful implementations, the understanding of how to effectively use information in enabling and supporting the development of digital PSS is still limited and the convergence of the two domain is creating difficulties both for academics and practitioners that should address a level of complexity that is continuously increasing. Indeed, both considering a literature analysis and an analysis of industrial requirements, several aspects of the implementation of services based on digital technologies and data collected along all the product lifecycle, are still open.

Specifically, the thesis will be focused on the concept of Data-Driven PSS (DDPSSs) which are PSS solutions, composed of a hardware part made of one or more SCPs, and a service part that is provided and delivered on account of the primary source data gathered by the product and sensors at customer locations, which imply the creation of a value stream through data exchange and analytics.

And, among the different challenges that have been identified, the following ones are considered:

- A lack of systemic understanding of the possibilities that technologies and data availability open in the service field;
- The interdisciplinarity of digital project and the technological competences that need to be developed from manufacturers;
- The increasing complexity of services that are developing into complete solutions and are expanding beyond their traditional coverage area;
- The need for guidance in the development of data-driven service solutions, to enable firms to leverage data to create value, and
- The changes and evolutions of the entire service ecosystem, both considering technological provider but also the possibilities for other actors to contribute to the service offering accessing and sharing resources, including knowledge and capabilities and reshaping the value creation structure.

Objective and research questions

Given the prementioned context, where a clear overview of data-driven possibilities into the service context and how to approach their development is not extensively discussed yet, this thesis aims to contribute to the development of systematic knowledge in the context of DDPSSs, both to the academic and to the practitioners' domains, formalizing their characteristics and providing a methodology for their development. Precisely, the presented dissertation provides an answer to the following RQs:

RQ1: Which are the characteristics and specific features of DDPSS that differentiate them from the traditional PSS?

DDPSS is an innovative concept with respect to traditional services. Nevertheless, a clear and complete landscape of the emerging possibilities is still missing. **There is the need to comprehend those new offers deeply and to generates order and synthesis on the actual state of the art defining specific characteristics they have**. This holistic picture would also support manufacturers and academies to understand which new approaches are needed to overcome challenges.

RQ2: How is it possible for a manufacturing firm to move from data acquisition, enabled by the integration of sensors with products and by connectivity, to DDPSS offerings?

Data exploitation is recognized as a new source of value in service offerings. However, research on this emerging trend is still at the beginning, and additional studies are required. Given the current state of the art, **there is a need for structured approaches that can lead companies to extract valuable information from data gathered**. Moreover, there is no clear **methodology focusing on the integration of data gathered from product and sensors in a PSS**, and studies on the **design of new product-service concepts using those type of data systematically** are rare.

Methodology

The research questions have been addressed employing different research methodologies that have also been selected considering the practical nature of the presented thesis, which is grounded into the practical problems and experiences by practitioners in the manufacturing industry.

Indeed, the presented thesis has benefited from a three-year sponsorship and collaboration with ABB company, in which the researcher had the possibility to perform action research. Therefore, at the basis of all developments, it is possible to notice a strong industrial influence and orientation of the work. Moreover, during the PhD path, the author has been involved in the ASAP Service Management Forum, where several other industrial companies contributed to the research for multiple case studies, which enable the author to reach a higher level of generalization of outcomes.

From a more theoretical perspective, over the course of the PhD, other methodologies have been adopted:

- A systematic literature review has been performed from the early stages of the research and has been updated until the end of the project, considering relevant publication into the Industry 4.0 data-related technologies and in the Servitization domains;
- Theory building and conceptual modelling have also been applied for the creation of a framework that resulted in the answer of RQ1.

Figure 1 represents the framework that guided the research, also providing information on the structure of the thesis, reporting the Chapters where the specific part is covered.

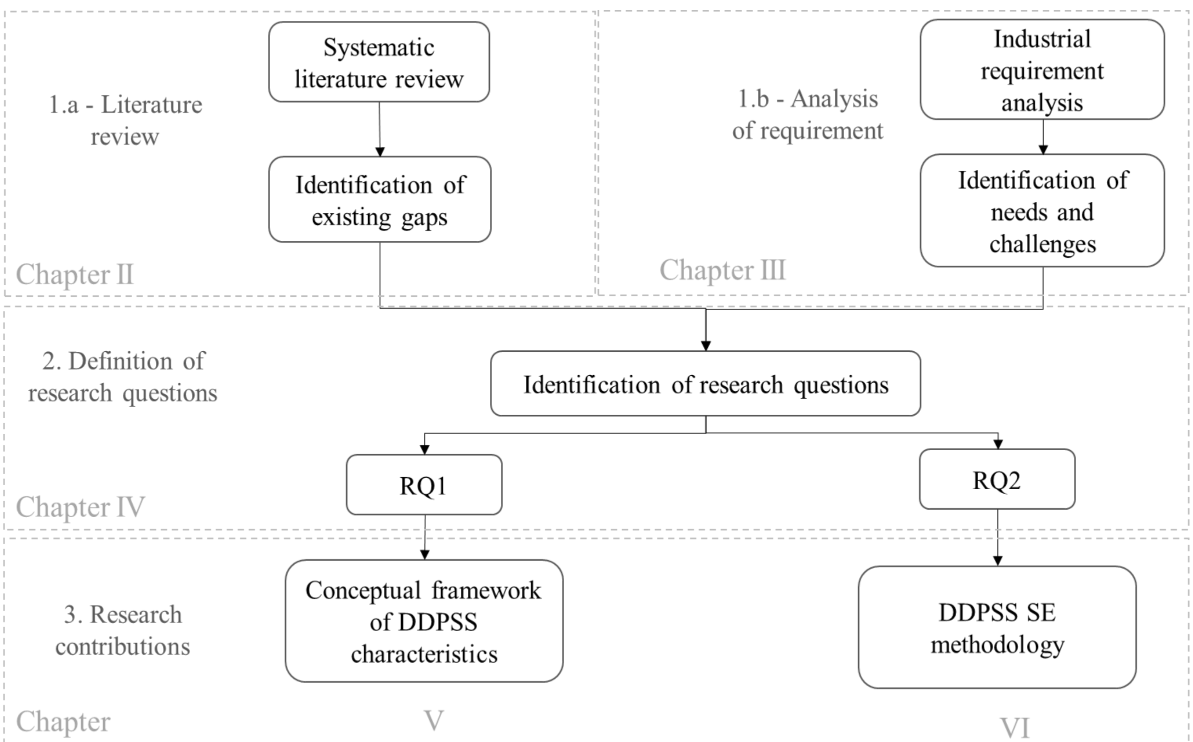


Figure 1 - Research Framework

Research outcomes

Considering **RQ1, the researcher has developed a two hierarchical conceptual framework**, intending to provide a tool that is able to represent B2B DDPSS typologies, according to their specific characteristics that have been identified from an iterative analysis of literature and case studies.

The analysis leads to the definition of four main characteristics that are:

a. ***Data Source,*** which identifies available or potentially available data, to be integrated into the service offered by the manufacturing company and represents the potential of enlarging the service scope and reaching a system-level vision;
b. ***Data Visibility,*** which represents in this work the level of visibility and access to data from different actors, that can be defined as customers, service provider but also other specific;
c. ***Response mechanism,*** which describes the output of the data analytic phase, that may support customer decision-making or actuate autonomous reaction; and
d. ***Decision Ownership,*** that identifies who perform the decision. Particularly, this dimension defines if service providers are adopting a passive or proactive strategy towards service provisions and define who is responsible for the decisions and assumes the risk of it.

Each dimension has also been divided into different categories, that represent the different possibilities that the dimension allows. Matching the different dimensions six different typologies emerged, that may be replicated in three different layers that represent possible service scope, i.e. functional, operational and business.

The framework has been validated with seven different case studies, to determining if all the relevant strategic dimensions were considered. A final case has also been developed considering the descriptive potential of the framework for the current situation but also proposing the possible future state of the company, to show how it is possible to use the framework also to start thinking of possible future directions. Finally, general benefits that may be reached both from the customer and for the PSS provider are defined for each of the service typologies identified, considering the cross-case finding and all the discussions that have been arisen during interviews with practitioners.

This framework provides a twofold contribution: on one side an academic contribution is offered, with respect to the synthesis of previous research and the definition of a common understanding of the characteristics of those service solution. On the other side, the framework also resulted in an actionable tool for practitioners, since it enables them to map their actual portfolio of DDPSSs and to think about additional offers by looking into the spaces of the framework that are not cover yet, as demonstrated in the application case.

Considering **RQ2**, **the researcher has developed a Service Engineering methodology**, that is tailored for B2B DDPSS, whit a specific focus on service and data module. The methodology has been inspired by the SErvice Engineering Methodology (SEEM) (Pezzotta et al. 2014). Additionally, it includes necessary features of DDPSS, which are: (i) enlargement of service scope, (ii) data availability, (iii) software-based solutions, (iv) modularity and reusability principles and (v) value chain perspective. The methodology has also been based on experiences and experiments carried out within the ABB context in the form of action research. Indeed, together with the digital team, the researcher worked on the development phases of digital solutions, based on data collection.

The DDPSS SE Methodology resulted in seven phases, which are (1) definition of service scope, (2) customer need analysis, (3) requirement analysis, (4) competitor analysis, (5) PSS design, (6) technical assessment and (7) value assessment, that are in some cases further decomposed into sub-phases. The work has been focused explicitly on the first five phases and considered the last one as a point to be further investigated into future development. Considering technical assessment, instead, it is possible to state that it does not represent a critical phase, at least into ABB context. For each of the considered phases, one or more methods have been proposed and adopted.

The methodology has been developed considering literature and theoretical contributions and has been applied in the context of ABB to provide its actionability. It has also been validated with different possible users inside the industrial context, showing positive feedback regarding its clarity, completeness, consistency and usability and generally with the possible adoption of it.

As for the framework, also the DDPSS SE methodology provides contribution both to the literature and to the industrial domain. Indeed, it provides further work into the Digital Servitization research stream, aiming to fill a literature gap that emerges regarding the definition of structured approaches leading to the development of DDPSS considering service and data perspectives. On the other side, it is also a practical tool that companies may adopt into the early stage of DDPSS SE, supporting them into the realization of a successful data-driven servitization path.

Conclusion and Limitation

The rise of digital technologies, and the availability of data that can be achieved with their utilization, brings a broad spectrum of opportunities and challenges and let to a level of complexity that was not present before, at all service lifecycle steps, struggling many companies in the realization of the potential benefits. The presented thesis contributes both from a theoretical lens and from the practical point of view to the successful realization of DDPSS, considering the clarification of their characteristics and typologies and defining a service engineering methodology for their development. As a general remark, the thesis is oriented on the DDPSS concept, strongly focusing on the service part that is provided and delivered on account of the primary source data gathered by the product and sensors at customer locations, while it does not extensively consider the implication on the hardware part, i.e. the product. Additionally, the research started with a high-level investigation of two general concepts, that further research could address from different perspectives and deepening into specific aspects considering for example the availability of customer-generated data, or the utilization of innovative data analytics techniques to exploit data potential.

Even considering the predefine research boundaries, several aspects can be further investigated and explored, considering, for example, to extend the proposed DDPSS framework to include also technologies and business models, or deeply address all the Phases of the methodology that has been less explored, dedicating more attention to the integration of all the different modules which compose a DDPSS. Despite some possible improvements, an open research direction clearly emerged from the literature review and is concerned with the definition of ecosystem structures and the value creation mechanism in new configurations that DDPSS stimulate. Some preliminary insights have been reported both considering the values that the different typologies of DDPSS create and with the proposal of Phase7 into the SE methodology. Nevertheless, only limited work has been performed on it in the presented thesis, paving the way for further research.

Moreover, since the work befitted from a scholarship from ABB, all the research received a strong influence from their environment, which was the primary setting of the researcher. This fact affected in part the generalization of results; indeed, the DDPSS framework has been validated with the support of several other companies, while the DDPSS SE methodology has been applied and validated only with ABB because it requires high commitment from the company in order to be completed. Given that, a natural development of the presented work would be the application of the methodology in other companies, to enforce the already reported results.

Research contributions

The contributions of this research are concerned with the DDPSS, providing a conceptual framework definition and categorization of those services, proposing a related methodology helping practitioners in understanding how to move from data acquisition to information and knowledge generation, to create value for the company, the ecosystem, and the customers in a value co-creation setting.

During the three years of the research, scientific contributions on the topic have been written and published, as reported in Table 1. The table shows explicitly the relation between the different publications with the content of the presented research. The results of these works have been used in the different part of the work, for the analysis of the literature or to explore and answer the research questions illustrated in Chapter IV and aimed at covering the literature gaps while meeting the industrial needs and requirements.

Other contributions elaborated from the researcher are reported in Table 2.

Table 1- Scientific contributions

Pertinence	***Contribution***
Context analysis	"Industry 4.0 data-related technologies and servitization: a systematic literature review" ***Zambetti M***., *Pinto R., Pezzotta G* (2020) APMS 2020 conference
	"Enabling servitization by retrofitting legacy equipment for Industry 4.0 applications: benefits and barriers for OEMs" ***Zambetti M***., *Khan M. A., Wuest T., Pinto R (2020)* 48th SME North American Manufacturing Research Conference
	"A patent review on machine learning techniques and applications: depicting main players, relations and future landscapes" ***Zambetti M.***, *Sala R., Russo D., Pezzotta G., Pinto R. (2018)* Proceedings of the XXIII Summer School "Francesco Turco" –Industrial Systems Engineering
RQ1	"From Data to Value: how are B2B companies working on the data-driven PSS transformation?" ***Zambetti M.,*** *Adrodegari F., Pezzotta G., Pinto R., Barbieri C.* Submitted to the XXVI Summer School "Francesco Turco" – Industrial Systems Engineering
	"From Data to Value: conceptualizing Data-Driven Product Service Systems" ***Zambetti M.,*** *Adrodegari F., Pezzotta G., Pinto R., Rapaccini M., Barbieri C.* Production Planning & Control (Accepted March 2021)
	"Understanding Data-Driven Product Service System characteristics: a conceptual framework for manufacturing applications" ***Zambetti M***., *Adrodegari F., Pinto R., Pezzotta G., Saccani N. (2020)* Proceedings of the XXV Summer School "Francesco Turco" – Industrial Systems Engineering
	"Data lifecycle and technology-based opportunities in new Product Service System offering towards a multidimensional framework" ***Zambetti M***., *Pinto R., Pezzotta G. (2018)* 11th CIRP Conference on Industrial Product-Service Systems

RQ2	"Exploiting data analytics for improved energy management decision-making" ***Zambetti M.,*** Cimini C., Pirola F., Pinto R. (2019) Proceedings of the XXIV Summer School "Francesco Turco" – Industrial Systems Engineering "How to select the right machine learning algorithm: a feature-based, scope-oriented selection framework" *Sala R., **Zambetti M.**, Pirola F.., Pinto R. (2018)* Proceedings of the XXIII Summer School "Francesco Turco" –Industrial Systems Engineering
Future development	"Impact of platform openness on ecosystems and value streams in Platform-based PSS exemplified using RAMI 4.0" ***Zambetti M***., Blüher T, *Pezzotta G.,* Exner K., *Pinto R.,* Stark R. (2020) APMS 2020 conference

Table 2- Additional scientific contributions

Contribution
"Applying simulation for sustainable production scheduling: a case study in the textile industry" Pirola F., ***Zambetti M.,*** Cimini C.* Submitted to the 17th IFAC Symposium on Information Control Problems in Manufacturing
"A network design model for a meal delivery service using drones" Pinto R., ***Zambetti M***., Lagorio A., Pirola F. (2020) International Journal of Logistics Research and Application
"A network design model for food ordering and delivery services" ***Zambetti M***., Lagorio A., Pinto R. (2017) XXII Summer School "Francesco Turco" – Industrial Systems Engineering
"Eggs are broken, so now what? A stakeholder management perspective of the Volkswagen's Dieselgate" ***Zambetti M***., Kalchschmidt M. (2017) Production and Operations Management Society (POMS) Conference 2017

I. INTRODUCTION

The presented chapter is an introduction of the central area of the research and provides a necessary background for the understanding of the positioning of the presented work. Starting from the definition and the contextualization of the two main trends that are challenging industries in this decade, i.e. Industry 4.0 and Servitization, a more in-depth analysis has been conducted at the crossroad of the two, where a newly emerging research stream has been identified, namely Digital servitization. Within this area is it possible to notice how the topic of data availability and the consequent possibility to create value is recognized as a key driver of success in the transition toward advanced services, but remains underexplored, leading to the definition of the main scope of the research which will be focused on Data-Driven Product Service System (DDPSS). The concept of DDPSS is also defined in the presented Chapter.

In the end, a readers guide is also provided, which briefly explains the content of all of the other chapters that constitute the corpus of the presented work.

1. Context of research

1.1. Industry 4.0 and Servitization

Originated in Germany in 2011, the term "Industry 4.0" refers to a paradigm shift from automated manufacturing toward an intelligent manufacturing concept, enabled by the adoption of digital technologies and associated paradigms, to achieve a higher level of operational efficiency and productivity, as well as a higher level of automation (Kagermann, Wahlster, and Helbig 2013). In the view of Industry 4.0 proposed by the German Government, the central aspect is the smart factory; however, smart mobility, smart grids, smart buildings and smart products are also considered. Regarding the smart factory, the German Federal Government presented the Industry 4.0 paradigm as an evolving structure in which Cyber-Physical System (CPS) use the available information from manufacturing and logistics systems to reach an extensively automated exchange of information to fulfil the agile and dynamic requirements of production and to improve the effectiveness and efficiency of the entire industry (Lu 2017). Industry 4.0 not only rely on CPS, but encompasses numerous other technologies, such as the Internet of Things (IoT), Big data analytics, cloud technologies, cybersecurity, virtual and augmented reality, smart sensors, simulation, additive manufacturing, advanced robotics, energy-saving technologies, horizontal and vertical integration (Mittal, Khan, and Wuest 2017). All together they support the transformation process of a traditional manufacturing process into fully digitized and intelligent systems that can create value for industrial activities (Müller, Buliga, and Voigt, 2018; Liao, Deschamps, Loures, and Ramos, 2017). Adopting such technologies, mature industries are now facing a transformation towards a digitalized era, where machines, devices and products can be interconnected to adapt themselves and be flexible to quickly attend to market changes (Wei, Song, and Wang 2017). This phenomenon is also leading to higher efficiency in traditional production relationships among all the actors into the value chain, considering suppliers, producers, and customers (Hofmann and Rüsch 2017). Even though manufacturing is the main focus, the impact of Industry 4.0's technologies is more far-reaching: indeed, one of the biggest growth potentials is recognized in the paradigm shift from a traditional product orientation to the provision of bundled solutions (Kamp, Ochoa, and Diaz 2016).

The concept that manufactures need to leverage innovative combinations of services and products to increase the scope of their value creation activities and to face the increasing global competition is not new. Schmenner (2009) demonstrate that manufacturing firm began to combine products and services even in the 19th century and from 1988, when the phenomena became notorious in the literature under the term *"Servitization*"(Vandermerwe and Rada, 1988; Kowalkowski, Gebauer, and Oliva, 2017), it has been widely discussed and investigated from different perspectives. Motivations at the basis of the service-oriented strategy adoption can be different, going from competitive motivations (T. S. Baines et al. 2009) to demand-based motivations (Wise and Baumgartner 1999) or economic ones (Oliva and Robert 2003). The servitization strategy amplifies the focus on customer needs and embraces concepts of "value-in-use" and "co-creation" of value by providing services. The concept of service-dominant logic (SDL), has also been developed in opposition to the goods-dominant logic (Vargo and Lusch 2004), heightening the fundamental role of service that becomes the basis of exchange, through goods. Based on this knowledge, servitized manufacturers are gradually offering performance-based or outcomes-based contracts (e.g., customer support agreements, risk and reward sharing). Those offerings represent new business models based on the integration of products and services in a bundle, usually aimed to fulfil customer needs often considering a lower environmental impact, and they are also known under the term "*Product-Service System (PSS)*" (Mont 2002),

Servitization is nowadays omnipresent in manufacturing enterprises (Neely 2013), which provide, from a customer-centric perspective, a combination of products, services, support and knowledge (Baines et al. 2009). Nevertheless, the evolution toward servitization does not necessarily lead to successful results. Indeed, if not supported with the right know-how, it can result in limited payoffs and insufficient revenues, namely "Service Paradox" (Opresnik and Taisch, 2015). Moreover, customers' expectations are becoming more complex, often based on what a product does for the user and not on the product itself (Mont, 2002; Sawhney, Balasubramanian, and Vish, 2004). In order to overcome these challenges and successfully implement servitization, companies need to find appropriate strategies and approaches (Oliva and Robert 2003). Adopting digital technologies has always been recognized as a possible successful way. In the light of this, it is not surprising that the provision of services relying on digital technologies is increasing, and represents a fruitful sub-stream of research, known as *"digital servitization"* (Lerch and Gotsch, 2015; Vendrell-Herrero, Bustinza, Parry, and Georgantzis, 2017). Indeed, digitalization enhances operations in a cost-efficient way and enables service quality through better resource allocation and more accurate information sharing inside and outside the boundaries of the firm. Moreover, the adoption of digital technologies may help manufacturing firms to add services to their offerings (Vendrell-Herrero et al. 2017; Coreynen, Matthyssens, and Van Bockhaven, 2017), improve service quality and reduce operational costs (Kowalkowski, Kindström, and Brehmer 2011). Nevertheless, according to recent literature, research on digital servitization, even in a fast-growing phase, is still in its infancy, and that the knowledge is fragmented across different research streams (Paschou et al. 2020). Moreover, it is possible to notice that the incipient literature on the topic provides little support to the understanding of the connection between Servitization and Industry 4.0 (Frank et al., 2019). Particularly, since Servitization and Industry 4.0 were born from different and stand-alone research fields, it is possible to notice how the former is centred on customer value from a management perspective (Díaz-Garrido et al. 2018), while the latter emphasizes the manufacturing process value from engineering and computer science point of view (Liao et al. 2017). Thus, consideration of the connections between these two fields needs to be deeply investigated, to create synergies between Service and Industry 4.0 and blurring the boundaries between managerial and technological perspective.

1.2. Digital servitization and Data-Driven Product Service System

As understood in the prementioned context, in the last decade, two recent macro-phenomena and trends are specifically challenging the manufacturing strategies, that are Servitization and Digitalization (Frank et al., 2019) and by merging these two macro-phenomena, a new sub-stream of research has been derived, named 'Digital Servitization' (Vendrell-Herrero and Wilson 2017). Digital servitization is defined as the provision of "IT-enabled (i.e. digital) services relying on digital components embedded in physical products" (Schroeder and Kotlarsky 2014). In this regards, Information Communication Technologies (ICT), IoT, cloud computing, data analytics, and the possibility to integrate information along the value chain in real-time, has been recognized as the most relevant technologies (Ardolino et al. 2016). ICT provides the right infrastructure to enable a smarter way to deliver the service to the customers and create the potentiality to extend the service offering. It enables services such as remote diagnostics, automatic software updates but also better control and additional possibilities into all the alternative to ownership (Suppatvech, Godsell, and Day 2019) that were usually in the form of pay per use and pay per results (Tukker 2004). The advent of IoT enables devices to connect with each other and thanks to the transmission to remote servers, it becomes technologically easier to offer tailored-made functions (Cenamor, Rönnberg Sjödin, and Parida 2017). Furthermore, IoT supported the development of Smart Connected Products (SCP) that are products composed of three core elements (Porter and Heppelmann, 2014): (1) the physical components, (2) smart components and (3) connectivity components enabling connections with the product. The result of such digitalization of products and infrastructures is enabling companies to offer Smart PSS, where the digital connectivity between components allows their autonomous interaction and the development of new functionalities. Indeed, IoT and connected products are at the basis of customer asset virtualization, continuous monitoring and automatic adaptability of the system. Those innovations are also supported by cloud computing, which supports the process of delivering scalable and expandable software services using internet technologies and cloud platform which provide an excellent environment for large-scale data analysis processing. In this sense, servitization literature has suggested that a platform approach may allow manufacturers to overcome the service paradox (Eloranta and Turunen, 2016; Pekkarinen and Ulkuniemi, 2008). As a consequence of the adoption of all the above mentioned technologies, the volume of data that a manufacturer may retrieve, especially through product usage, increases exponentially. This large amount of data, matched with effective data analytics tools, can become a key source of value creation (Rymaszewska, Helo, and Gunasekaran, 2017). Indeed, collecting and elaborating data from the installed base has been recognized as a key aspect for manufacturers to servitize as it can enable sophisticated service offerings and new service-oriented business models (Adrodegari and Saccani 2017). Additionally, the adoption of an intelligent infrastructure enables gathering feedback and data collection from the later stages back to the earlier stages of the product lifecycle (J. Lee, Kao, and Yang 2014) and creates the potential to enhance the value co-creation process, which is one of the central premises of the service logic (Belvedere, Grando, and Bielli 2013). Since data exploitation is recognised as a new source in the service offerings (Opresnik and Taisch, 2015), some exploratory studies on the increasing importance of data and information as a source of value in the service context are now emerging (Baines and Lightfoot, 2014; Opresnik and Taisch, 2015; Lehrer, Wieneke, vom Brocke, Jung, and Seidel, 2018) and successful cases of service based on data gathered from connected products are demonstrating the potential of data availability. For instance, Kone, one of the largest global elevator companies, developed sophisticated condition monitoring and predictive maintenance services together with IBM. Both these services are based on the advanced elaboration of data gathered from the connected elevators ("Kone Website"). Again, in the heavy transport sector, Volvo Trucks have developed a whole range of services based on data gathered from products, to support the operations of transport companies (“Volvo Trucks Website”). They offer maintenance services, which are provided preventively and in a smarter way, but they also included fleet management services, which allows the customer to plan and optimise deliveries, also considering the possibility of offering return trips to third parties, to minimise the cost of the return, and the driving profile of a driver, thus optimizing the efficiency of the delivery. Nevertheless, despite notable cases and several studies recognize the potential of data into the servitization domain, the understanding of how to effectively use information in enabling and supporting the development of digital PSS is still limited (Cenamor, Rönnberg Sjödin, and Parida, 2017; Lim, Kim, Kim, Kim, and Maglio, 2018) and research dealing with data-driven service offering is scant and widespread among different streams and disciplines. It is worthy to mention that a common agreement on what “data-driven services” are, is still missing. Different notions are arising on this frontier, and even if academics agree on the fact that digitally-enabled PSS rely on data streams, a unique definition is not present. Generally speaking, Chen et al., conceptualize two main application areas concerning the utilization of data to provide services, namely Data-as-a-Service” (DaaS) and “Analytics-as-a-Service” (AaaS), considering data utilization to provide to the customer either raw and aggregated content or analytics components and infrastructure adjusted to fit company-specific requirements (Chen et al. 2011). This definition is not limited to services connected to physical products. Conversely, other authors define data-driven services as detached from products and based on data such as customers’ online behaviours recorded and used for strategic marketing planning and service management (Huang and Rust 2013). Further works, instead, introduced the concept of data-driven services as exclusively linked to physical products, where the main data source is the product itself and the service should complement them in a meaningful way (Henning Kagermann et al. 2014). Then, more recent literature refers to “data-driven service” as a synonym of “smart service” (Mittag, Rabe, Gradert, Kühn, and Dumitrescu, 2018) considering most of the times the realization of a CPS, that is also able to interpret data and autonomously decide and control the system (Anke, 2019).

In light of this, looking at the new frontiers that are arising for what concerns the interdependence between technological advancement and the service offering, the data dimension emerges as an imperative path. Accordingly, the researcher will investigate the interrelation between Industry 4.0 and Servitization domain, considering specifically data-related technologies and their impact on the servitization strategy. Particularly, the research will focus on Data-Driven PSS offerings and their development approaches, since result critical gaps from the literature analysis and challenges for the industrial realities, as it will be extensively explained in Chapter II and III. This thesis will only consider product-generated data, neglecting user-generated data (Zheng et al. 2018) and limiting the research to data obtained mainly from the end-products . Tush, in this work, data-driven services will be considered as "services which are characterized by a digital component and build on data from intelligent and connectable products. They create benefits for companies and/or customers through generation, collection, analysis and/or combination of internal and external data" (Kampker et al. 2018). ***The concept of Data-Driven PSS (DDPSSs) is here defined as a PSS solution, composed of a hardware part made of one or more SCPs, and including a service part that is provided and delivered on account of the primary source data gathered by the product and sensors at customer locations. Moreover, a DDPSS implies the creation of a value stream through data exchange and analytics.***

2. Readers guide

Chapter II reports an ***analysis of the literature review***. It constitutes the first and necessary phase of the research path, which aims at setting the pillar or the research, analysing the existing knowledge in the field. The analysis has been undertaken with a rigorous process of the systematic literature review considering the Servitization domain e the technologies belonging to Industry 4.0 related to data. The scope of this phase is twofold, on one side it is aimed at clarifying which are the main trends that are taking shape, on the other, it would clarify the existing gaps concerning the two domains. After the structured initial review, literature analysis has been continuously performed throughout the three years to maintain the body of knowledge updated with newly published works.

Chapter III is dedicated to the ***identification of company requirements.*** Given the fact that the research has been supported by ABB, in order to help the company during the transition towards servitization based on new technologies, an analysis of company needs have been performed in parallel to the literature review. This intensive collaboration has enabled the definition of industrial criticalities and the better definition of the better path to pursuit considering the aim to contribute to the industrial domain, firstly for the financing company, but also other reality facing the same necessities.

Additionally, another interesting collaboration has been set with the ASAP forum. This collaboration allowed listening to multiple and heterogeneous industrial realities working on the realization of DDPSS, and understanding common criticalities.

Chapter IV is concerned with the ***definition of research questions and thesis structure***. It summarizes the gaps that have been defined as a consequence of the literature review and the industrial needs. Based on them, two research questions, that are going to be addressed and discussed in the remaining, are formulated. Then the structure of the research is explained, considering both the underlying framework, the steps and the methodologies applied during the three years of research.

Chapter V reports the first main contribution of this thesis, which is related to the ***definition of service typologies with respect to data-driven possibilities***, providing a holistic view on the key characteristics of DDPSS and addressing RQ1. It includes both the theoretical development of the framework, the different case studies analysed for its validation and a final application of the model, to also demonstrate its practical contribution.

Chapter VI addresses the RQ2 and ***presents a Service Engineering (SE) methodology, designed for DDPSS***, comprehensive of seven different phases for which methods and tools have also been proposed. Starting from a traditional SE approach, the researched defined the needed changes and feature to be integrated in accordance with the data-driven peculiarities. The chapter contains the theoretical explanation of different phases and methods proposed, an application case that has been developed on ABB experience and a final validation with possible ABB users.

Chapter VII ***concludes the work***, summarizing the contribution of the presented research and presenting future research directions that have been identified to develop extensions and improvements of the presented work.

II. LITERATURE REVIEW

1. Objectives

Considering the prementioned context, this chapter aims at exploring the state of the art in the Servitization and Industry 4.0 fields, in order to understand the point of contact between them and derive interesting research directions that could be pursued. As an initial point, the research wanted to approach a broad perspective and include papers not only focused on the “digital servitization” stream, but also works that are also focused on the technological and industrial perspective that is not always covered in the servitization domain (Frank et al., 2019) and understand which are the main gaps in the digital servitization approach, considering the data that can be gathered by the product and sensors at customer locations. Indeed, a boundary into the research has been added for what concerns the technological aspect, which is dedicated to the technologies that are related to the data collection and management, as better defined in the keyword selection, but without including specific data analytics methodology to cover a high-level perspective. The literature aims at describing the content and the quality of knowledge already available, presenting the significance of previous works. Moreover, the researcher wants to provide a critical overview of the existing knowledge and identify literature gaps as well as future research directions that will guide the research objectives of the presented thesis.

2. Methodology

The systematic literature review approach is widely used to investigate the advancement of a specific stream of research as well as to propose recommendations for future studies (Goodwin and Geddes 2004). A systematic review can be distinguished from different types of publication for its scope and rigorous. Indeed, a rigorous scientific investigation follows a specific, explicit and, therefore, reproducible methodology and approaches to identify, collect, evaluate and discuss relevant issues on the specific topic (Richard J and David B 1984), to limit bias and random errors (Cook, Mulrow, and Haynes 1997). The researcher decided to follow the PRISMA statement (Moher, David Alessandro Liberati, Jennifer

Tetzlaff Douglas 2009), which defined a detailed set of principles to be respected during the systematic literature review, that are reported in Figure 2. The framework has been developed aiming at facilitating the elaboration and reporting of a systematic review and to support rigid methodology. It was firstly developed in the context of health care and clearly specify that some steps, as meta-analysis, are specifically arbitrary and may or may not be used to analyze and summarize the results of the included studies, as specified by authors. In this research, the four main steps, which are (1) *identification*, (2) *screening*, (3) *eligibility* and (4) *included* has been rigorously performed according to the presented methodology. An additional carefulness has been taken adding a backward approach on the most cited references, aiming at including all the possible relevant peace of knowledge discussing the topic.
All steps followed in this work are detailed described in the following paragraphs.

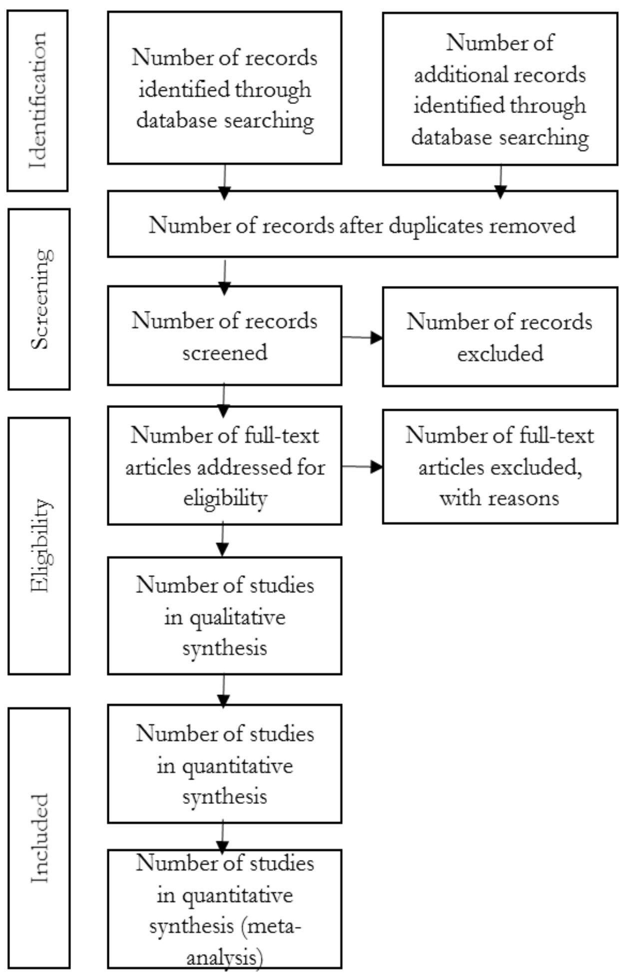


Figure 2 - PRISMA Statement (adapted from Moher, David Alessandro Liberati, Jennifer Tetzlaff Douglas, 2009)

2.1. Keywords definition

In order to create a representative corpus of documents for investigation, the first step was the definition of a set of keywords to be included in the research, and for all of them, the specific meaning of the word or concept has been defined. A set of synonymous has also been included in the query have been decided. The keywords have been chosen separately for the two different topics. For what concern *"Industry 4.0"* author considered only concepts related to the possibility to gather data and enable data utilization. For *"Servitization"*, two different trends had been considered from the literature, which expresses a similar concept: "Servitization" and "Product Service System". The two following tables, Table 3 and Table 4, report synonyms and the detailed description of the keywords chosen, respectively for the technology and servitization domains.

Table 3 - Keyword selection – Technology domain

Keyword	Synonyms	Definition	Reference
Internet of Things	IoT, Internet of Everything, Industrial Internet of things, Industrial internet	IoT is defined as a new paradigm in which things or objects provided with radio-frequency identification, tags, sensors, actuators, etc. – through unique addressing schemes – being able to interact with each other and cooperate with their neighbours to reach common goals	(Giusto et al. 2010)
Internet of Services	IoS	The IoS consists of participants, an infrastructure for services, business models and the services themselves. Services are offered and combined into value-added services by various suppliers; they are communicated to users as well as consumers and are accessed by them via various channels.	(Buxmann, Hess, and Ruggaber 2009)
Digitization		Digitization—i.e. the networking of people and things and the convergence of the real and virtual worlds that are enabled by information and communication technology (ICT)—will be the most powerful driver of innovation over the next few decades and will act as the trigger of the next wave of innovation. It will transform all key infrastructures in fields such as energy, mobility, healthcare and manufacturing	(Henning Kagermann 2015)
Analytics		The techniques, technologies, systems, practices, methodologies, and applications that can be used to analyses data.	(H. Chen and Storey 2012)

Keyword	Synonyms	Definition	Reference
Big Data		Big Data can be defined as data characterized by specific characteristics, that can be summarized using the notion of "5Vs". 'Volume' which highlights the large amount of (Russom, 2011); 'Velocity', which is the frequency or the speed of data generation and/or data delivery (Russom, 2011); 'Variety' represents the fact that data are generated from a large variety of sources and formats (Russom, 2011),'Value' in order to stress the importance of extracting economic benefits and 'Veracity' that refers to the quality data and the level of trust in various data sources (White, 2012).	(Fosso Wamba et al. 2015)
Cloud Computing		Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resource that can be rapidly provisioned and released with minimal management effort or service provider interaction.	(Demirkan and Delen 2013)

Table 4 - Keyword selection – Servitization domain

Keyword	Synonyms	Definition	Reference
PSS	Product Service System, Product-Service System, PSS, Integrated product service, Industrial Product Service System, Integrated Product-Service Offering, IPSO, Product service System, Integrated Solution	Product service system (PSS) is an innovative business model where a product and its associated services are combined together in a certain proportion and reasonably provided to customers, by selling or renting or even mixing.	(Qu et al. 2011)
Servitization	Servitisation, Servicisation, Servicification, Servicizing, Service Infusion, Hybrid Value Creation, Service-oriented Manufacturing, Customer Solution, Product-extension service, Dematerialization	Servitization is the innovation of organizational capabilities and processes to shift from selling products to selling integrated products and services that deliver value in use.	(Lightfoot, Baines, and Smart 2013)

Considering the technological dimension, no specific data analytics methodologies have been included since the presented SLR does not aim to investigate the implications of data analytics techniques on the service offering. Moreover, the inclusion of data analytics methodologies would have introduced a high number of papers in the research, since the high number of methods should have been included, like data mining, AI, Principal Component Analysis etc., or all the ML algorithms like Neural Networks, Random Forest tree, HD scan etc. Therefore, the inclusion of all data analytics technologies would have expanded the pool of paper, nevertheless, authors decided to limit the SLR to high-level keywords, defining close boundaries but also resulting in a limit of the presented work.

2.2. Paper identification and screening

After the definition of the keywords, the research was performed using Scopus database, and the queries have been constructed linking two by two the different concepts, so a total number of six queries has been used, matching one concept from technologies domain and one from servitization. Each query was limited to the English language and year of publication after 2011 since the Industry 4.0 concept emerged in 2011. Moreover, to limit the scope of the research, subject areas included were: (1) Engineering; (2) Computer Science; (3) Business Management & Accounting;(4) Decision Science.

Since the high number of papers related to those queries, the research was limited to articles published in journals. This choice also allows better-quality control in the publications. (Light and Pillemer, 1984). In the end, each query was defined as explained in Table 5, searching the specific keywords in the papers' title and abstract.

Table 5 - Queries definition

(1)	((TITLE-ABS-KEY (pss*) OR TITLE-ABS-KEY ("Product-Servi* System*") OR TITLE-ABS-KEY ("Integrated product servi*") OR TITLE-ABS-KEY ("Industrial Product servi* System*") OR TITLE-ABS-KEY ("Integrated Product Servi* Offer*") OR TITLE-ABS-KEY (ipso) OR TITLE-ABS-KEY ("Integrated Solutio*") OR TITLE-ABS-KEY ("Product servi*")))
(2)	((TITLE-ABS-KEY (serviti*ation) OR TITLE-ABS-KEY ("Smart service") OR TITLE-ABS-KEY ("Servi* Infusion") OR TITLE-ABS-KEY ("Hybrid Value Creation") OR TITLE-ABS-KEY ("Service-oriented Manufacturing") OR TITLE-ABS-KEY ("Customer Solution*") OR TITLE-ABS-KEY ("Product-extension service*") OR TITLE-ABS-KEY (demateriali?ation*))

(3)	((TITLE-ABS-KEY ("Big Data") OR TITLE-ABS-KEY ("Cloud Computing") OR TITLE-ABS-KEY (digiti?ation) OR TITLE-ABS-KEY (analytic*)))
(4)	((TITLE-ABS-KEY (ios) OR TITLE-ABS-KEY ("Internet of Serv*")))
(5)	((TITLE-ABS-KEY ("Internet of Thing*") OR TITLE-ABS-KEY (*iot) OR TITLE-ABS-KEY ("Internet of Everything") OR TITLE-ABS-KEY ("Industrial internet of thing*") OR TITLE-ABS-KEY ("Industrial internet")))
	(1)AND(3); (1)AND(4); (1)AND(5); (2)AND(3); (2)AND(4); (2)AND (5)
AND	(LIMIT-TO (LANGUAGE, "English "))
AND	(LIMIT-TO (SUBJAREA, "ENGI ") OR LIMIT-TO (SUBJAREA, "COMP ") OR LIMIT-TO (SUBJAREA, "BUSI ") OR LIMIT-TO (SUBJAREA, "DECI "))
AND	(LIMIT-TO (PUBYEAR, 2019) LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) R LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011))
AND	(LIMIT-TO (DOCTYPE , "ar "))
AND	(LIMIT-TO (SRCTYPE , "j ")

2.3. Eligibility

Besides the filters described above in the research query, the author has inspected articles in three different rounds, increasing the degree of the analysis. First, titles have been read, and exclusion criteria were related to the ones that clearly were far from the research scope. Then abstract reading enabled to restrict the pool further and finally, the full text has been examined. Not all the full-text reading led to a positive inclusion in the final pool since the number of papers was too large to conduct an in-depth investigation and some works were not eligible. The final pool has been defined considering papers strictly related to the final scope of the review, which is to the define correlation between Industry 4.0 technologies and the servitization trend. Thus, a first reading was made to decide the level of coherence and adherence of the content with the scope. Papers have been excluded mainly for two reasons:

(1) The degree of technology innovation was not so high to be included in the wave of industry 4.0, even if the paper was focused on servitization and its enhancement thanks to technologies;

(2) High technological applications were not aimed at the servitization transformation, and it was not even possible to assume that those solutions would be used as service applications.

Following those steps, the final pool resulted in 86 papers.

After this selection, and before performing additional analysis, a backward analysis of the most cited references has been performed. As suggested by Henry Small in 1973, this procedure may help to include in the analysis works that can be related to the topic under interest, but which are not included in the final pool. The analysis has been performed with VosViewer, and the procedure reveals 13 works to be analyzed. On those papers, the same steps as described above have been performed and, in the end, none of them was added to the pool. The 85% of them did not satisfy the inclusion criteria on the year of publication, and the other two papers were excluded one at the title screening and the second at the Abstract.

Table 6 - Co-citation analysis

Title of the reference	**Co-citation**
Servitization of business: adding value by adding services	6
Lifecycle oriented design of technical product-service systems	5
Theory building from cases: opportunities and challenges	4
Managing the transition from products to services	4
The servitization of manufacturing: a review of literature and reflection on future challenges	3
Product-service systems: a literature review on integrated products and services	3
The drivers of customer attractiveness, supplier satisfaction and preferred customer status: a literature review	3
Closed-loop PLM for intelligent products in the era of the internet of things	3
Determine the importance weights for the customer requirements in QFD using a fuzzy AHP with an extent analysis approach	3
Fuzzy multiple goal programming applied to TFT-LCD supplier selection by downstream manufacturers	3
Clarify the concept of product-service system	3
How to make a decision: the analytic hierarchy process	3
Eight types of product-service system: eight ways to sustainability? experiences from Suspronet	3

In Table 7 each step of the eligibility phase made to reach the final corpus of paper included in the review is reported. The table summarizes the number of papers included, divided for each sub-query. As it is possible to notice, the richest poll is linked to the query (3). Terms included in that query are less than some others but represents different concepts, thus, having a larger number of papers, it is coherent, and it does not represent a specific interest in some areas. On the other side, it is also possible to state that terms related to Product Service System are preferred to the one of Servitization, in terms of the number of papers published including the selected words.

Table 7 - Summary of the steps and results followed to reach the final corpus of paper

Protocol steps	N° of publications			
		PSS	Servitization	
Final pool after screening	Internet of Thing Internet of Service Technologies	96 173 465	117 53 98	**1002**
DUPLICATES REMOVAL				**605**
Full Text Available	Internet of Thing Internet of Service Technologies	55 117 243	60 37 50	**562**
Title Screening	Internet of Thing Internet of Service Technologies	36 70 98	41 32 56	**333**
Abstract screening	Internet of Thing Internet of Service Technologies	23 28 40	31 4 29	**155**
Full-text reading	The degree of technology innovation was not so high to be included in the wave of industry 4.0, even the paper was focused on servitization and its enhancement thanks to technologies	-33		**86**
	High technological applications were not aimed at the servitization transformation, and it was not even possible to assume that those solutions would be used as service applications	-36		
Backward on most cited references	13 paper identified that did not match the requirements			-
Final pool	Closely related to the scope of the research			**86**

3. Bibliometric Analysis

Initial investigation has been performed adopting bibliometric analysis, to define bibliographic data quantitatively. This first assessment is useful to get information concerning performances of the sample, understand trends or patterns in publication for research areas, years of publication, most productive authors and organizations, journals, citation etc.. Bibliometric analysis is also supported by bibliometric mapping, which are quantitative methods for visually representing scientific literature based on bibliographic data in a specific domain or topic. Bibliometric mapping has been elaborated with VosViewer software, and all maps reported in the following paragraphs have been extracted from it.

3.1. Descriptive analysis

The initial descriptive analysis investigates the interest over time, geographical areas and journals where the theme is traded, and which fields are covered. Results revealed that the topic is under ferment. Figure 3 is representative of the year of publication of the journal, and it is possible to see a positive trend over time, that has been increased from 2016 on.

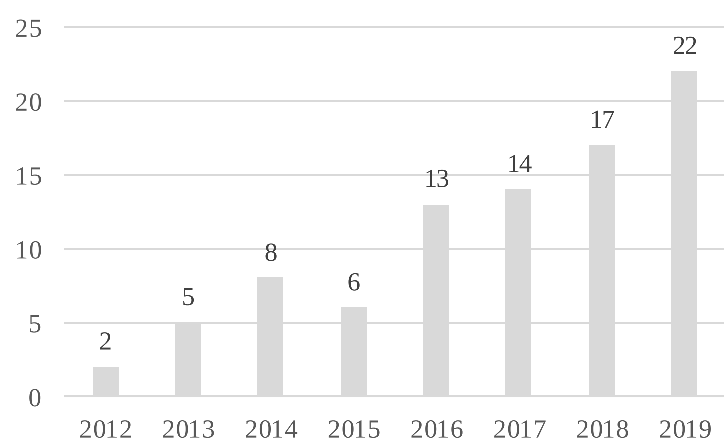


Figure 3 –Number of publications over years

Figure 4 illustrates the geographical areas where the authors' affiliation is located. Interest in the topic is spread in all countries and aggregating data, European researchers wrote the majority of papers, but east regions, as well as US, are devoting their efforts in the same direction.

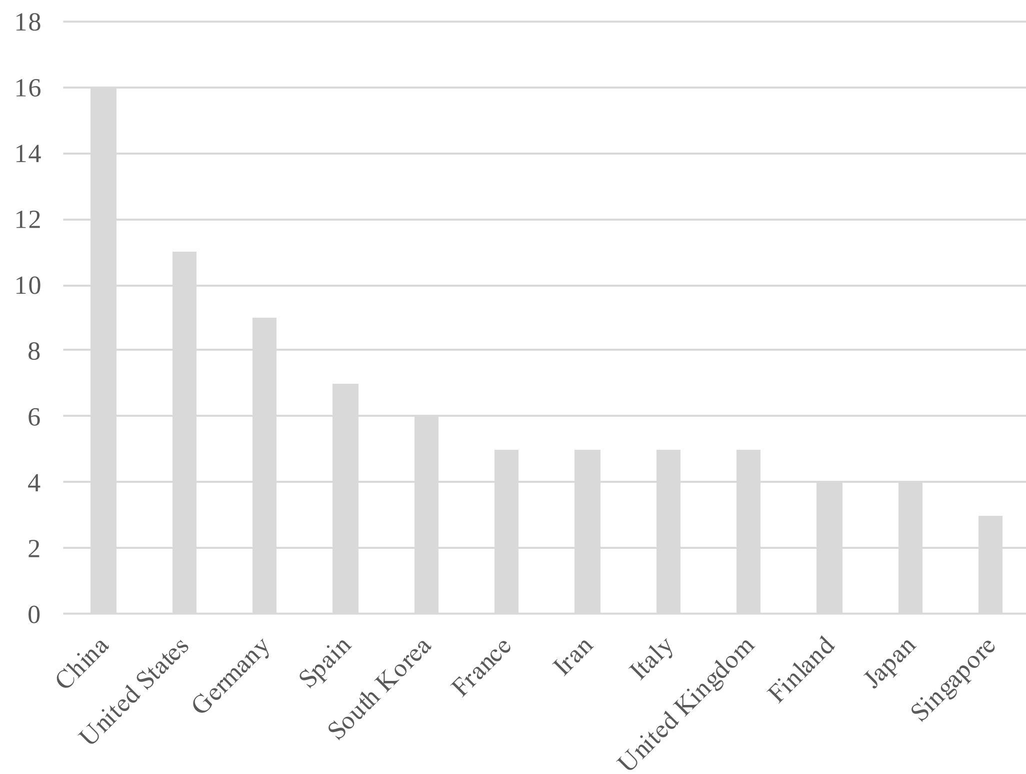


Figure 4 - Number of papers published per region (with at least 3 publications)

The sources of papers, which are reported in Figure 5, show that there are not specific journals that are debating the topic, and that the interest is spread over different fields. The first journal in terms of number of publications in the field resulted in the "Journal of Ambient Intelligence and Smart Environment", with seven papers, followed by the International Journal of Manufacturing research with four papers as the IEEE Internet of Thing Journal. All the others counted three or fewer publications. This fact means that in the field of Smart Environment the topic is highly debated; nevertheless, the subject has no border in terms of applicability and that the path thought digital servitization is strongly interdisciplinary, indeed it is possible to notice that Journals are different in terms of disciplines, even all belong at least in one of the categories defined in the filter "SUBJAREA" and most of them have a technical imprint, they are fragmented from technology, management, service, marketing and other fields. From this preliminary investigation is emerging that interest in the topic is far-reaching, both in terms of time, space and fields.

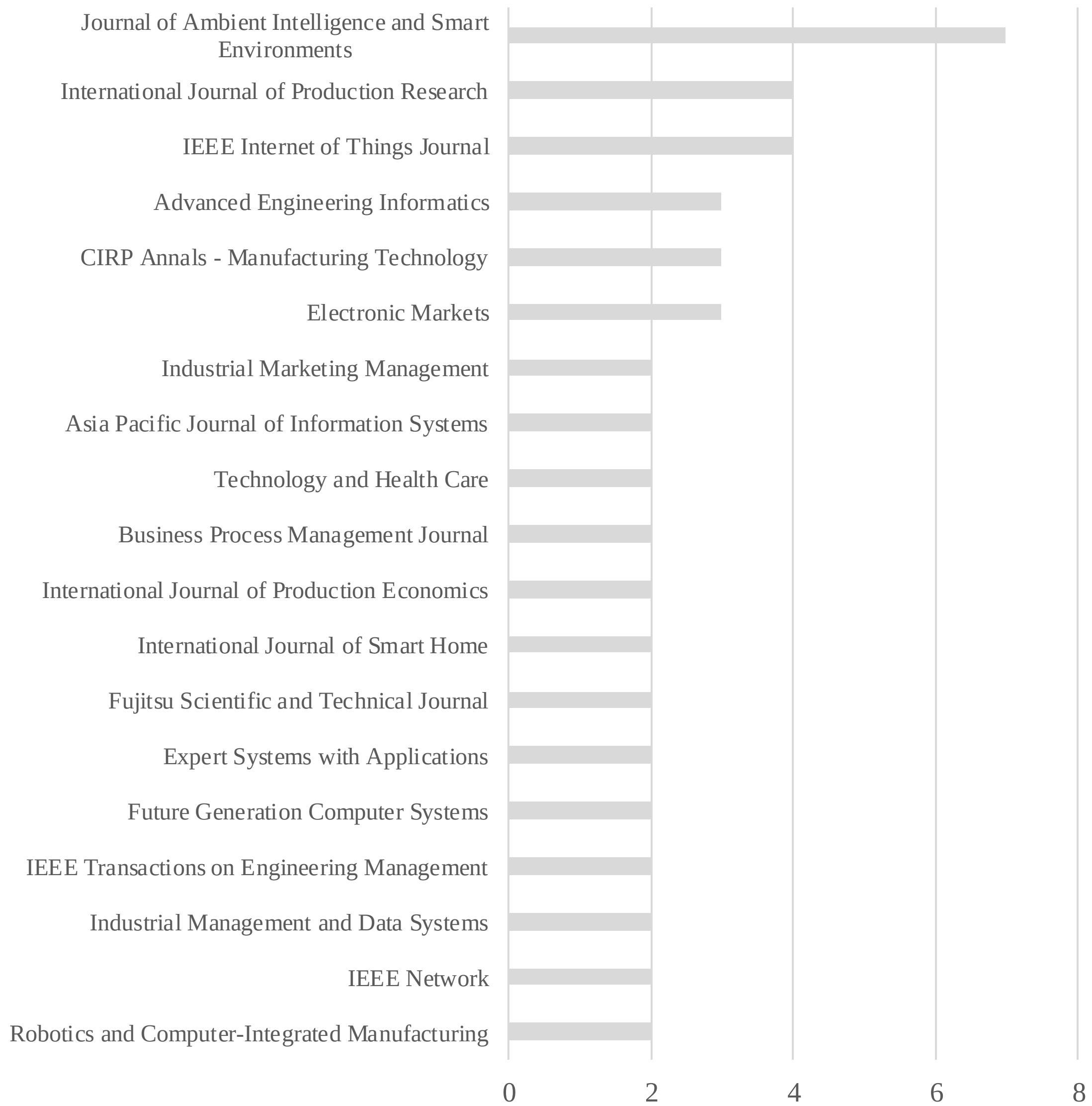
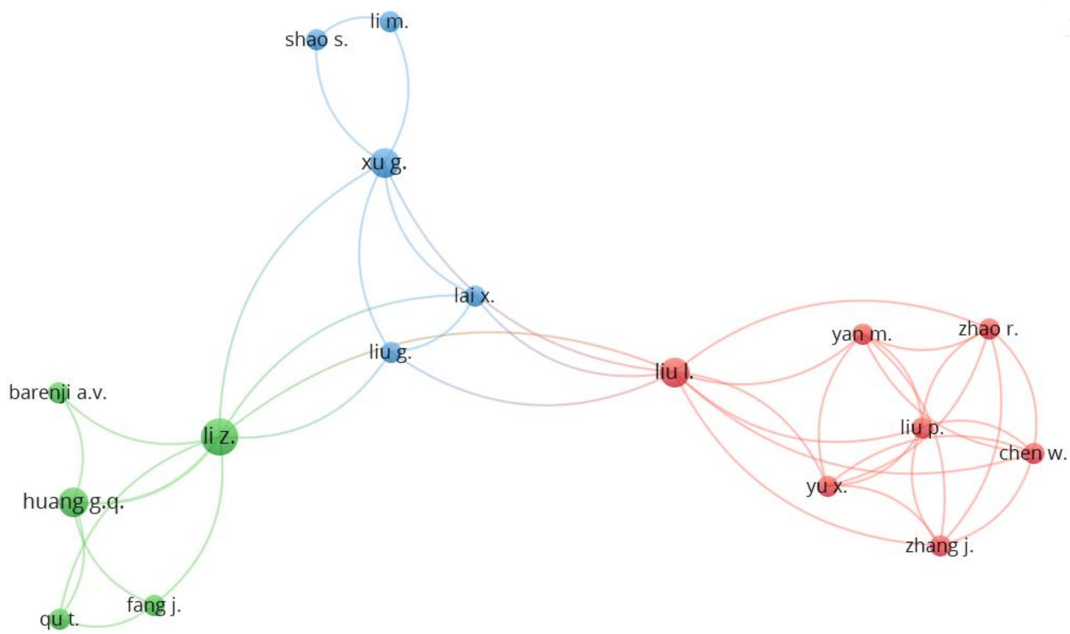


Figure 5 - Journal count with respect to the Source Title (with at least two documents)

Looking at authors affiliations, no specific organization emerges as the most productive on the topic, reflecting another time the heterogeneity of the final pool of paper and the fact that the theme is far-reaching, and it is approached from different points of view, still lacking from a specific community. Among affiliations, there are also some technological companies, like Cisco, Ericsson, Fujitsu, IBM, Panasonic, Siemens and Telecom and also some medical private institutions and hospitals. The author also investigated co-authorships of articles, keeping attention on the authors' affiliations. Figure 7 reports the results of such analysis, showing which authors collaborate with each other in the writing of paper in the final pool. As it is possible to notice there are few recurring collaborations, indeed only three clusters collaborating have been identified, and their affiliations are in both cases The Guangdong University of Technology and the University of Hong Kong



Cluster	Authors	Affiliation
1	Chen W., Liu L., Liu P., Yan M., Yu X., Zangh J. Zhao R.	Guangdong University of Technology, University of Hong Kong
2	Barenji A. V., Fang J, Huang G.P., Li Z., Qu T.	Guangdong University of Technology, University of Hong Kong
3	Lai X., Li M., Liu G., Shao S., Xu G.	Guangdong University of Technology, University of Hong Kong

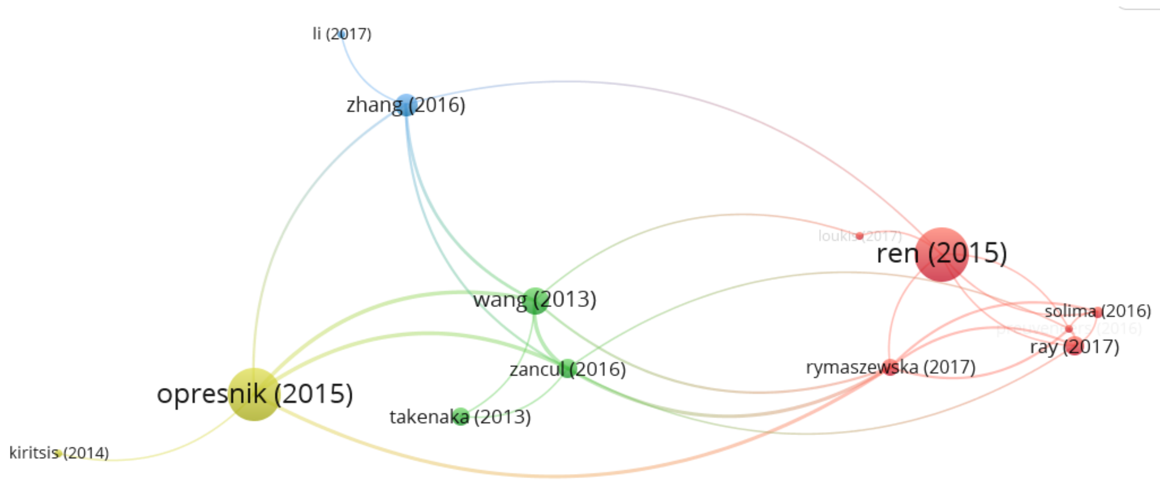
Figure 6 - Co-authorship map – VosViewer elaborated

Another aspect investigated regards citations. The number of citations per article has not been considered in the filter during the creation of the pool of paper to have a complete view of the topic. As it is possible to see in Table 8, which reported the five most cited articles in the pool of paper under analysis, the first article is on Service topics, which highlights the importance of the theme in the field. The other most cited papers are related to the cloud manufacturing concept, internet of energy and big data in servitization.

Table 8 - Top cited articles

Title	N° of citation	N° of citation/ year	Ref.
Service Research Priorities in a Rapidly Changing Context	234	46,8	(Ostrom et al. 2015)
A collaborative and integrated platform to support distributed manufacturing system using a service-oriented approach based on cloud computing paradigm	119	17	(Valilai and Houshmand 2013)
The internet of energy: A web-enabled smart grid system	77	9,6	(Bui et al. 2012)
Cloud manufacturing: From concept to practice	66	13,2	(Ren et al. 2015)
The value of big data in servitization	63	12,6	(Opresnik and Taisch, 2015)

While considering citations inside the pool of paper, i.e., if some of the paper in the pool cited some of the others in the pool, few of them resulted connected, as shown in Figure 7. The size of the label and the circle of the author denotes the weight of the paper, so the bigger is the node, the higher is the number of times that the paper has been cited inside the pool. The pool presented only ten works that are linked together, that can be aggregated into four non-overlapping clusters, represented in different colours. From the analysis of papers into the clusters, it is possible to notice that Cluster 3 is the only one that focuses only on one topic, i.e. the logistics, while the other clusters contain papers both related to industrial and service domains.



Cluster	1st author	Title
1	Kiritsis	ICT supported lifecycle thinking and information integration for sustainable manufacturing
	Opresnik	The value of big data in servitization
2	Wang	Analysing network uncertainty for industrial product-service delivery: a hybrid fuzzy approach
	Zancul	Business process support for IoT based product-service systems (PSS)
	Tenkenka	Product/service variety strategy considering mixed distribution of human lifestyles
3	Li	Iot-based tracking and tracing platform for prepackaged food supply chain
	Zhang	Smart box-enabled product–service system for cloud logistics
4	Ren	Cloud manufacturing: from concept to practice
	Solima	Managing adaptive orientation systems for museum visitors from an IoT perspective
	Ray	Internet of things for smart agriculture: technologies, practices and future direction
	Rymaszewska	IoT powered servitization of manufacturing – an exploratory case study
	Loukis	Inter-organizational innovation and cloud computing

Figure 7 - Bibliographic coupling of documents – VosViewer elaborated

A further investigation has been performed on the keywords. Authors' keywords analysis revealed a total number of 328 single keywords, and the most cited are reported in

Figure 8. Internet of Things (IoT) is the most common, followed by Product Service System and Servitization. As it is possible to notice, few keywords are used several times, but with

a deeper analysis, most of the times, similar concepts have been explained with different terms: e.g. electronic health records; e-Health; healthcare asset management; m-Health; remote healthcare system; smart health and telecare are all words referring to one topic.

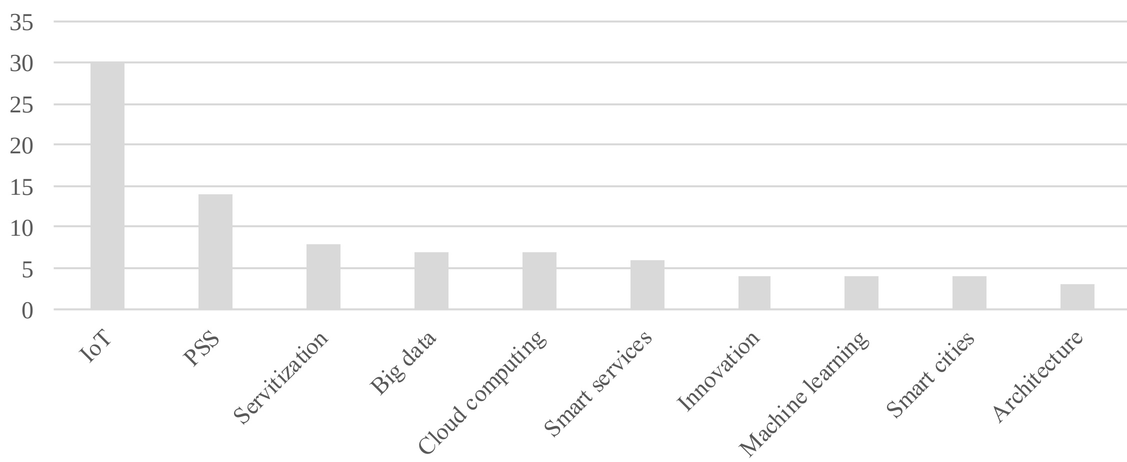
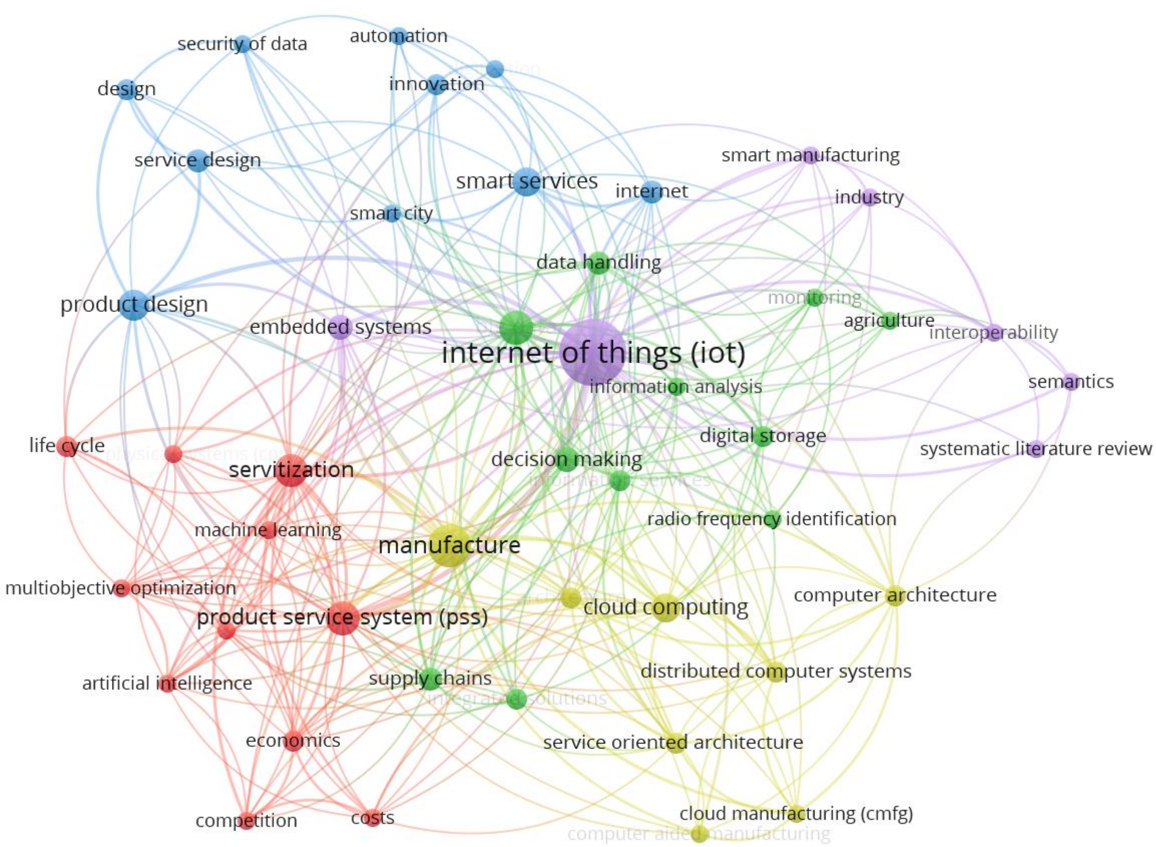


Figure 8 - Count of keywords (Top 10)

Keywords analysis is also useful to understand if all the important keywords are included in the initial queries. Words "*Innovation*", "*ML*", "*Smart City*" and "*Architecture*" are mentioned in the most used keywords and are not included in the initial search. Nevertheless, those keywords have not to be included in the queries since they are not directly linked with the research aim and the number of citations of the words can be considered not critical. "ML" is the only one that may be included considering the technological perspective but should be covered either by "analytics" or "Big data". Controversy, the fact that ML strongly emerges, help in comprehending which analytics are mostly applied.

After this first investigation, co-occurrences analysis and clusterisation of keywords have also been performed, to understand which keywords are usually related to each other. With the aim to obtain a comprehensive keyword map and reveal the most important keyword in the analysis, not all the keywords have been included but just the once with the most representative connections. Results are shown in Figure 9. The map represents the co-occurrence of keywords, by mean of links (row in the figure) between terms. Any pair of keywords can be described only with one link. Each link is associated with a strength, which represents, in this case, the number of publications in which two terms occur together. The size of the label and the circle of the keyword denotes the weight of the keyword, so the bigger is the node, the higher is the number of times that the keyword has been used globally. Different colours in the map exemplify different cluster of keywords. Particularly, we can notice five different non-overlapping clusters, and as it is possible to see, the IoT is the central node that connects different clusters. Looking at the keywords composing the clusters, it is possible to draw some preliminary consideration on the focus of papers. Indeed, Cluster1 and 3 refer to the service domains, matching respectively keywords related to the technological area and to the design perspective. Clusters 4 and 5 are, instead, mostly related to the Industry 4.0 concept including Architectures, Cloud Manufacturing and Smart Manufacturing, among others. In Cluster 2 Supply Chain emerges as linked with keywords related to data and information management.



Cluster	Keywords
Cluster1	**Product Service System, Servitization**, Competition, Costs, Cyber Physical Systems, Decision Support System, Economics, Life Cycle, Machine Learning, Artificial Intelligence, Multi-Objective Optimization
Cluster2	Big Data, **Supply Chains**, Decision Making, Integrated Solutions, Digital Storage, Information Analytics, Information Services, RFID, Data Handling, Agriculture, Monitoring
Cluster3	Product Design, **Smart Services** Automation, Design, Digitalization, Innovation, Internet, Security of Data, Service Design, Smart City
Cluster4	**Architecture,** Cloud Computing, **Cloud Manufacturing**, **Computer Aided Manufacturing**, Computer Architecture, Distributed Computer Systems, **Manufacturer**, Service Oriented Architecture
Cluster5	Embedded Systems, **Industry, IoT**, Interoperability, Semantics, **Smart Manufacturing**, Systematic Literature Review

NOTE: Clusters do not need to exhaustively cover all items in a map

Figure 9 - Keyword network map (VosViewer elaborated)

4. Content Analysis

The second level of investigation into the final pool has been performed adopting a qualitative analysis on the topic of the papers, analysing their research typology and methodologies, application fields, technologies and the general content.

4.1. Nature of research and validation methods

For what concern the nature of the research, most of the selected papers are explorative studies mainly focused on qualitative analysis. At the same time, another important percentage is more technological and deals with the development of a whole system, from the identification of the devices and architecture to the implementation of a demo or working system. Another interesting portion of research deals with the development of frameworks and approaches the research questions with a theoretical perspective, even for the validation case studies are generally used. In the remaining papers, the author found some studies proposing models, architectures and algorithms, and a limited number of reviews, that are not all developed with a systematic methodology. The platform development category includes all the works that were specifically focused on the platform feature and realized the application. Details on the number of publications related to each type of research are reposted in Figure 10.

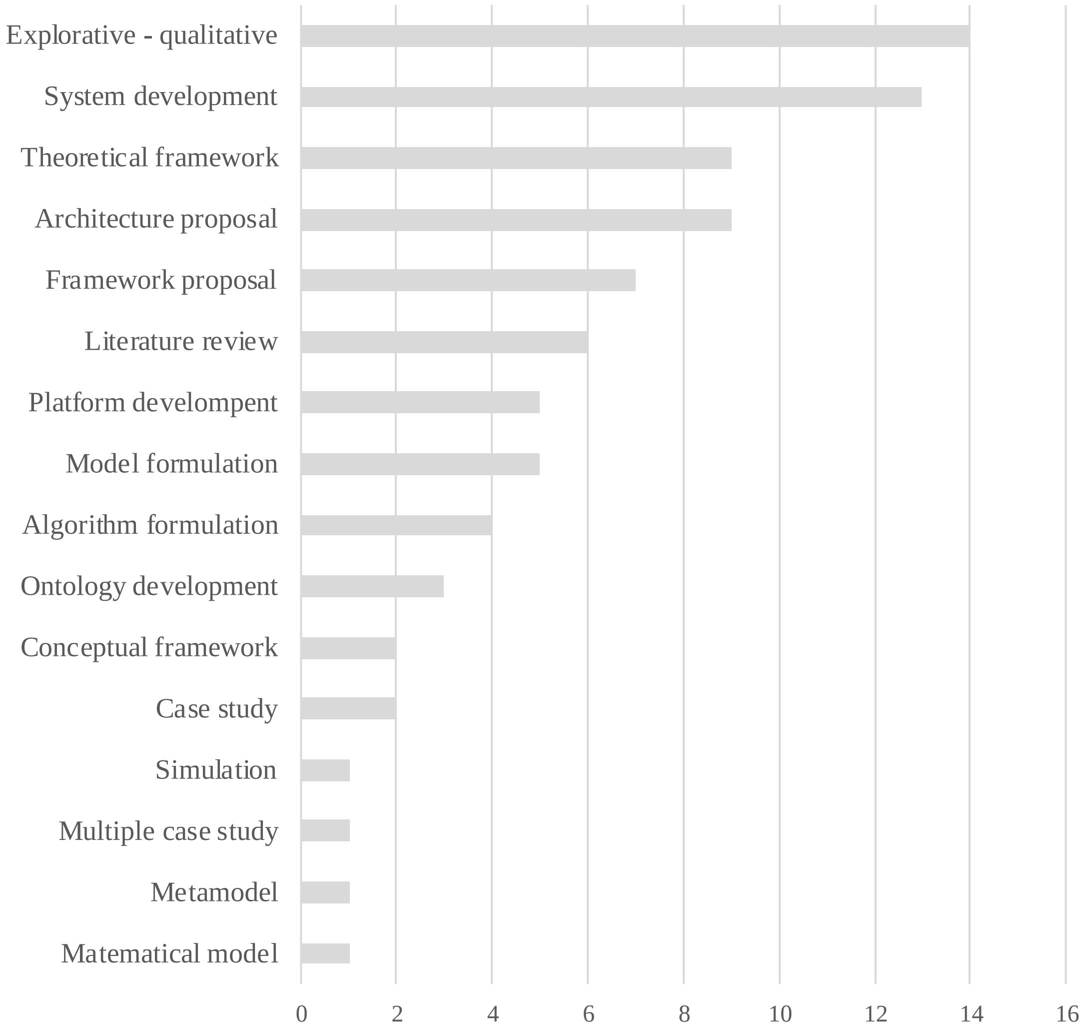


Figure 10 - Number of papers according to the nature of the research

The type of methodology used to validate the research has also been analysed, and as pointed out in Figure 11, the case study is the preferred methodology in order to develop and validate research findings. It is followed by use case and surveys. A smaller percentage uses multiple case studies and multiple-use case, showing the difficulties in finding more suitable cases for a specific application and the high level of resources to be allocated for those cases. There are other validation methods, like performance and acceptance evaluation, which are limited in the analysed papers.

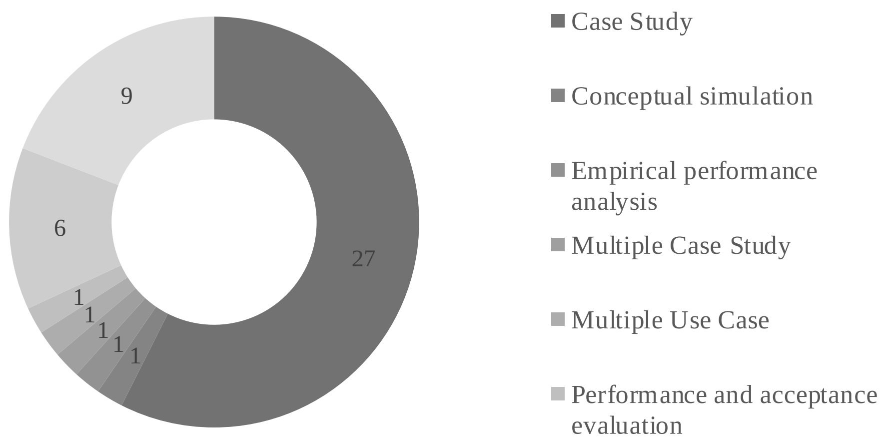


Figure 11 - Number of papers according to the validation methodology (where applicable)

4.2. Technologies and application analysis

Papers have also been analysed looking at the central technology described or used, to understand if some of those emerge over the others. As it is possible to notice from Figure 12, IoT, data analytics and Cloud Computing are the most cited technologies and they are also they are related one each other. IoT is a typical information and communication system, able to connect to the Internet, store and transmit information; thus, it is not surprising that is strongly related to data analytics.

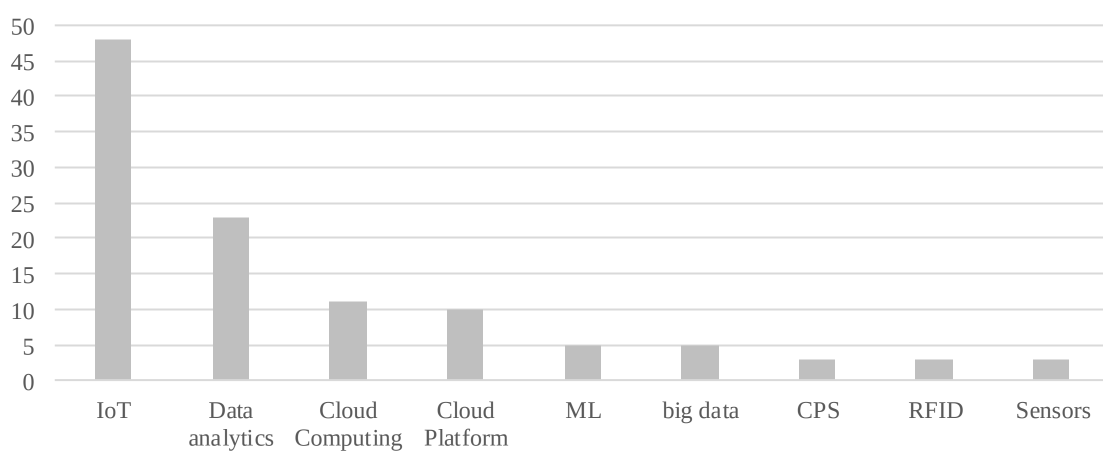


Figure 12 - Number of papers dealing with a specific technology

Additionally, IoT can automatically collect and process the information gathered from objects. Cloud computing, which is a computing mode based on the Internet, results as a perfect complementary technology, and cloud platform can provide an excellent environment for massive data qualitative analysis processing (Ardolino et al. 2016).

Looking at the application field that the paper deal with, there is no doubt that the intelligent environment has a core position, as emerged from the previous analysis on Journals. It refers to the capacity of sensing of ambient with respect to different factors and the consequent ability of the system to offer services based on necessity, either adapting or calling some "external entities"(Nixon et al. 2005). Nevertheless, as it is possible to see from Figure 13, there are not border in terms of applicability: Smart health care, Industrial operations, Smart city and Smart farming are also at the centre of the discussion.

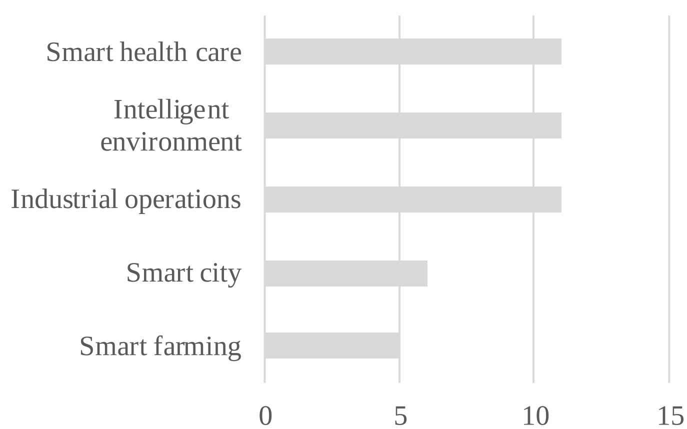


Figure 13 - Analysis of specific applications

Finally, in Table 9, relationships between technologies and the field of applications are reported, showing for each kind of application if one technology has been used at least in one publication. Cloud Computing and IoT are the most debated in the majority of fields, as also emerged from keywords. Data analytics has been considered in the technologies, but basically, it represents a different layer, since all technologies and applications need some data analysis to support. IoT is the most adopted technology for all applications, while some other technologies resulted more oriented to fewer applications, for example, CPS are used for industrial applications, while RFID is employed for Supply chains and Smart health care.

Advanced data analytics techniques are still poorly adopted, and ML algorithms are more exploited in comparison with AI.

Table 9 - Field of application - technology matrix

	CPS	Cloud Computing	Cloud Platforms	WSN	Data analytics	Geographic information	AI	RFID	IoT	NFV	Sensors	ML	Big data
Industrial applications	x	x	x		x				x	x		x	x
Intelligent environment					x				x				
Maintenance					x						x		
Marketing insight		x			x								
Pet care					x				x		x		
Smart city		x			x	x			x			x	x
Smart farming					x				x			x	
Smart grid		x			x				x				
Smart health care		x	x	x	x		x	x	x		x		
Supply chain		x			x			x					
Tourism					x				x				

4.3. Paper categorization

As already mentioned, the final corpus of paper resulted in being heterogeneous since the topic is widespread among different disciplines. Consequently, the researcher decided to categorize papers into homogeneous groups to provide a comprehensive overview of the topic. The categories have been established considering on one side the focuses introduced with the keywords that are related to the service domain and technologies, and on the other side, the most relevant perspectives underlined by the literature.

As mentioned in the introduction, digital servitization is a research stream already established, and it focuses on the company service transformation as the core aspect, considering that advancement in technologies are completely reshaping the way firms offer services (Lerch and Gotsch 2015). Digital servitization has been studied under different perspectives, generally highlighting the value that digital technologies can provide for the service value delivery to the customer. In particular, some studies demonstrated that digitization facilitates the development of cost-efficient operations and is an enabler of service quality through better resource allocation and more accurate information sharing inside and outside the boundaries of the firm (Kindström and Kowalkowski 2014). In accordance with that, attention has been focused by different academics on the integration of servitization and digitalization with other business dimensions, as the manufacturing process and the supply chain. The production perspective emerges, for example, in the work of Coreynen et al. (2017): they examined how digital technologies can enable different Servitization pathways proposing three different cases, that are Industrial, Commercial and Value Servitization Pathways (Coreynen, Matthyssens, and Van Bockhaven, 2017). Into the Industrial pathway, resources and capabilities are devoted to make the internal manufacturing operations smarter and provide new hybrid services for the clients. For what concern the supply chain, for example, Vendrell-Herrero et al., (2017) study how the dematerialization of physical products is transforming the way firms are positioned in the supply chain and their engagement with customers. (Vendrell-Herrero et al. 2017).

The same macro-areas also emerged from the keyword analysis performed in Section3, enforcing the considerations mentioned above, coming from the literature. Indeed, Cluster1 and 3 refer to the service domains, Clusters 4 and 5 are related to the Industry 4.0 concept including and in Cluster 2 Supply Chain emerges. Therefore, the author divided the corpus of the paper according to three different focuses, that are the service, the industry and the supply chain. An additional class has been also defined to represent research studies describing from a technological point of view some specific application based on Industry 4.0 technologies that could potentially be deployed as a service in many circumstances.

The classes have been named:

- (CL1) Digital servitization transformation;
- (CL2) Industrial servitization of operations;
- (CL3) Supply chain and network collaboration; and
- (CL4) Technological focus on specific applications.

Table 10 reports the number and the papers per each category.

Table 10 - Number of papers per categories and references

ID	Classes	N of papers	References (See Appendix A)
CL1	Digital servitization transformation	26	[1]-[26]
CL2	Industrial servitization of operations	10	[27] – [36]
CL3	Supply chain and network collaboration	10	[37] – [46]
CL4	Technological focus in specific applications	41	[47] - [86]

CL1 has been created considering papers that deal with digital servitization transformation. This pool represents works studying different aspects of the path of manufacturing companies thought the servitization paradigms leveraging the possibilities that technologies and data gathering are creating. What emerges is that the scope of the services is changing and expanding. Particularly, it has been found that products connectivity enables manufacturers to offer new services with new value propositions (Sambit, Vinit, and Joakim 2016). The manufacturer has the possibility to continuous auditing of customer operations and expands value creation having the ability to operate within the field of product use including services at the client's operation level (Kamp, Ochoa, and Diaz, 2016). Moreover, if the applications are into a business context, the need of a culture of trust with business partners, customer and users emerge more and more, since clients have no intrinsic interest in sharing operational data with machine tool contractor and to hook them up to their data gathering and processing systems (Kamp, Ochoa, and Diaz 2016), because of different privacy and security issues. In this view, value creation and co-creation are recognized as the basis of the deployment of such solutions.

CL2 deals with applications that employ digital technologies, resources and capabilities to make internal manufacturing operations smarter. Among them, an interesting part considers the cloud manufacturing paradigm as the major impact of service-oriented applications. Indeed, customers can have access to on-demand services, such as engineering design, simulation, production, assembling, testing and management (Ren et al. 2015). Some other works deal with the Industrial Product-Service System (IPS2), as an approach to operate in an efficient and effective service-oriented way, enhancing life cycles, delivering solutions that meet customer expectations, providing, for example, a tool to support firms into the decision of an IPPS adoption (X. Wang and Durugbo 2013).

CL3 is focused on the positive impact that the adoption of new technologies has on the collaboration practices in the value chain and on the other on the implication at the network level. From the analysis resulted that the adoption of intelligent products and the contribution of ICT enhancement can result in the integration of users together with producers and service providers in closed data and information loops, in a collaborative ecosystem. Inside those works, it is possible to find paper dealing with models supporting a service-oriented enterprise collaboration network (F. Zhang et al. 2012) Alternatively, describing the benefits of the IoT-based systems in the supply chain context (Li et al. 2017).

CL4 is the larger class and the most fragmented among different disciplines and field. Within the class, it is possible to find papers that for example describes the realization of a smart service system set up for the maintenance, remote failure diagnosis, quick service response, failure detection and iterative optimization of sugarcane harvesters (S. Liu et al. 2018). Other works describe IoT hybrid monitoring system for health care environments providing location, status, and tracking of patients and assets (Adame et al. 2018). Another proposes a Smart Service Orchestration Architecture to coordinate ubiquitous objects, create interlinked data, and implement versatile smart service in the Smart City context (You et al. 2019). Within this class, it is possible to find also works that are more focused on the manufacturing side (Shibata and Kurachi 2015) or supply chain and coordination mechanisms (Zhou et al. 2018) (Laubis et al. 2019). Overall, it is possible to state that with different perspectives and field of applications lot of paper deals with the design and development of complex solutions, which needs the technological competences in the realization of infrastructure, that should be reliable and secure, analytics capabilities and the know-how into the field of applications.

4.4. Services Characteristics

Final analysis has been performed for all the case studies and service examples reported in the pool of paper to understand the features of services based on technology. Adopting inductive reasoning, which has the scope to generate meanings from the collected data to identify patterns and relationships (Goddard and Melville 2004), the author investigated recurring traits of the services described and noticed three lenses of analysis to group them:

i. *Role of the physical asset:* This layer defines the role of the "hardware" part of the offering. Usually, in PSS literature, there are four components of the final solution, i.e. product, service, infrastructure and ecosystem (Mont, 2002) where product and infrastructures refer to the physical structures. Usually, the product had been recognized as the crucial component of PSS offering, on the contrary, during the analyses, the author noticed that the product-centric perspective was not present in the publications, showing how product digitalization and connectivity are leading to a paradigm shift in the role of the product that became part of the infrastructure as a means to deliver a service.

ii. *Service consumer:* The service user represents the consumer of the service or the final client of the data provided. Different final users can be identified in the publications, and not only customers or business customers were present, but there are also applications addressed to society and networks.

iii. *Data flow:* The result of data elaboration is generally a decision, an action, that can be directly performed by the system itself, thanks to automatisms and configuration ability. When a decision is critical or not obvious or not implementable by automatic logics, data are usually shown to a human operator, through a human-machine interface. This characteristic has also been pointed out by X. Liu et al., 2016, defining the use of data for smart services, either informing people to help them or managing objects directly.

Different categories included in the layer are better defined in Table 11.

Table 11 - Definition of classification

Characteristics	Categories included	Category description
Role of the physical asset	Product-centric	The product is the main focus of the offering, while the services are a collateral part.
	Infrastructure	The service is the main scope of the offering while the product represents a part that supports the delivery of the service
Service consumer	Product	Services are performed in order to maintain a product (e.g. maintenance)
	Operation	Services are performed in order to optimize company operations
	Network	Services aim at support coordination among different actors
	Person	Services that are directly provided to a final user
	Society	Services are performed for the society and the community wellbeing
Information flow	D2O	Data flows from product or/and informative systems is directed to the product again. Intelligent mechanisms are embedded in the product or in the IoT architecture, and they can perform some action based on embedded analytics and perform services.
	D2H	Data flows from objects or/and other informative systems into an intermediary platform for data analysis and visualization. Those platforms are the essential means to perform a decision based on data gathered. The system is not able to automatically perform a decision, but data or information are directed to a human operator.

Applications have been classified according to the predefined characteristics, considering that not all the cases were suitable for the definition of all of them, and some applications belong to more than one category per layer. Figure 14 represents a summary of applications grouping together different characteristics and thus identifies some recurring offering typology. As it is possible to notice, few applications are product-centric, i.e., depicting cases where the hardware part corresponds to the service consumer. Within this sample, applications refer, for example, to asset management applications, and data is collected and sent to a platform to support maintenance decisions (S. Liu et al. 2018). For all the other applications, the hardware part does not correspond to the consumer of the service and so not usually represent the core of the service offer. Within this group, it is possible to notice various service consumers, and different data flow. Applications addressed to private end-users or society that considers automatic response, are mostly focused on one side of the intelligent environment that automatically adapt to different situations (Stefan, Aldea, and Nechifor 2018) and on the other on smart cities (Mohammadi et al. 2018). Considering, instead, applications that elaborate signals from personal or other devices to show relevant information to the consumer or public institutions to support decision-making most of the applications fall under the health care domain (Ganapathy, Vaidehi, and Poorani 2015). Examples that are mostly focused on business customers can be divided into the ones who support operations and the ones that are used to share information and knowledge at the network level. Regarding operations, applications able to automatically take decisions represent the minority and the most advanced systems are focused on smart farming (Ray 2017). The other cases refer to the possibility to collect and analyse data to finally support human decision making, also considering that some decision cannot be performed automatically (Shibata and Kurachi 2015). On the other side, for what concern network application, the available pool reported only systems that support decisions, examples are IoT platform aimed at tracking and tracing product (Li et al. 2017).

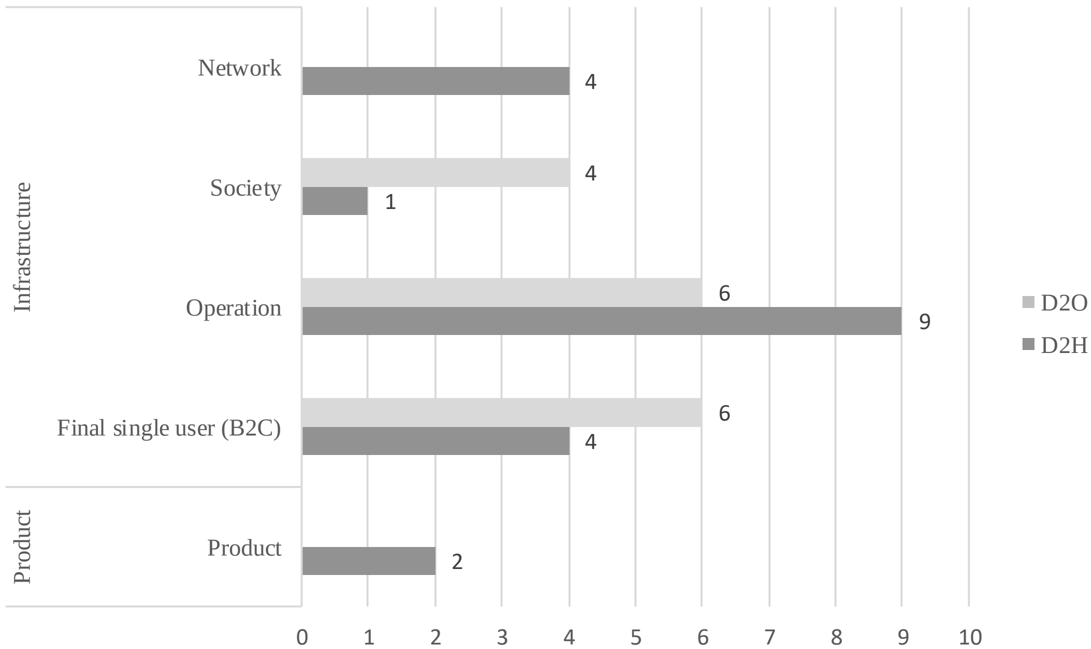


Figure 14 -Number of the paper belonging to the different predefined classification considering from left: Role of the physical asset, Service consumer and Information flow

5. Findings, gap and future research direction

The corpus of paper resulted heterogeneous and fragmented among different disciplines and it was possible to classify paper for clearly separate interests, revealing that the Servitization and Industry 4.0 domains maintain distinct knowledge and research stream, confirming, as highlighted by Frank at al., (2019) (Alejandro G. Frank et al., 2019) that the connection between them is still emerging. There are some initial attempts of overlapping, but authors maintain most of the time the two concepts disconnected, indeed, as it is possible to notice from the classification presented in this work, most of the studies into the CL1 do not consider the manufacturing perspective. In contrast, in the other three classes, the servitization perspective is weakly addressed. The specific focus on data remains poorly covered in the pool of paper and mostly appears as an underlying enabler. Indeed, studies either focused on the impacts of technologies on service offering (CL1) or the technical development of solution (CL4), without proposing a holistic view. It is also possible to notice both from the initial analysis and paper classification that most of them have a focus on technologies describing technical development of solutions, starting from the infrastructure to the realization of a platform on which is possible to see and use data. They usually refer to prototypes or demo, demonstrating that commercialized applications are few. Furthermore, it is possible to state that the service perspective is still emerging and is the most recent. The number of papers belonging to CL1, represents the 30% of the sample and most of them are published after 2016. Furthermore, most of these papers have an explorative and qualitative perspective, underlying the novelty of the phenomena (Figure 15). As it is possible to see, some works applying literature review are now emerging, but none of them adopted a systematic literature review. This novelty has also been confirmed by the keyword analysis related to the year of publication since words like “analytics”, “digitization”, “servitization” and “smart service” are mentioned mostly from 2017.

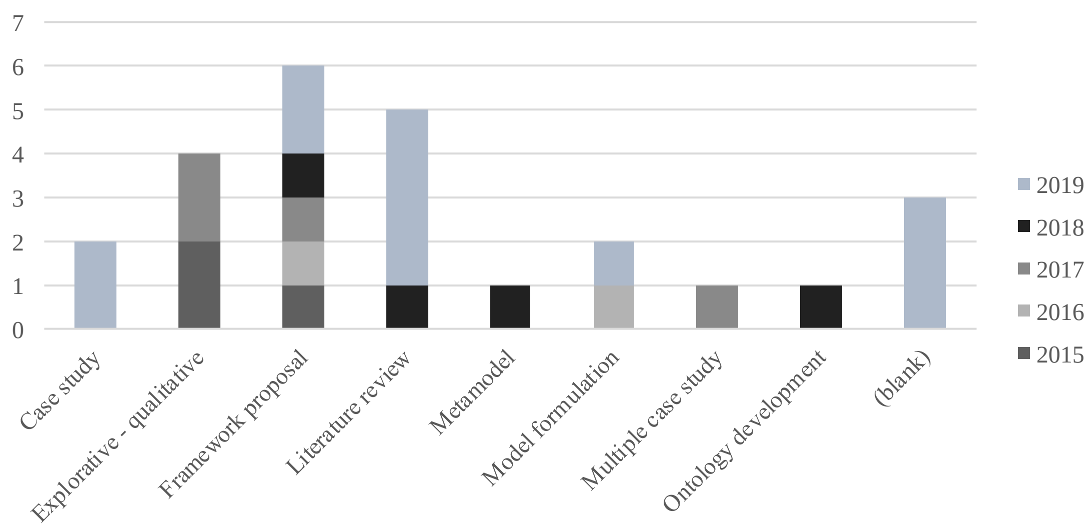


Figure 15 - Detail of the number of papers per year in CL1

This analysis explicitly reveals a lack of research on the topic within the service domain and state the need to move forward to create synergies between service and Industry 4.0 perspectives and blurring the boundaries among different pieces of knowledge. Consequently, considering the possibility to further integrate the relation of data technologies and possibilities into the service point of view and vice versa, some interesting direction emerges. Those directions are the result of a cross-analysis of the different classes and application examples, considering how to move forward to create synergies between them and blurring the boundaries among different pieces of knowledge.

5.1. Research direction 1

Technological advancement in product connectivity and data availability led to the offering of complex solutions rather than traditional PSS and the scope of the services is changing and expanding. Particularly, has been found that products connectivity enable manufacturers to offer new services with new service proposition, the manufacturer has the possibility to continuous auditing of customer operations (Sambit, Vinit, and Joakim 2016) and expands value creation having the ability to operate within the field of product use (Rymaszewska, Helo, and Gunasekaran 2017), including services at client’s operation levels. Smart connected product is seen as a service component, and a platform as a bridge from customer, product and service provider (Shin, Jeon, and Park 2016). Digital servitization is leading to a new concept of Product Service Systems, where the value of the product is still critical, but the value of the service and especially of the data provided to the customers are far beyond. The product in most of the cases lost its centric role and became part of the infrastructure that is used in order to enable the service while data gathered aims at covering the core offering. Usually, product-related services were related to the product itself; both respect its health status and its usage. As it is possible to deduce from Figure 14, only few papers have been found to belong in the product-centric category and they are focused on product maintenance. Within those examples, the scope of the service is also the product and data gathered were used into a specific application. Looking at other papers, it is possible to notice that the products play the role of infrastructure and are aimed at other aspects like operation and network coordination, person or society. Although some new streams of research are now emerging on “data-driven” services, a common agreement on the definition of what those services are is still missing and limited research is devoted to the definition of the unique characteristics of those services (Klein, Biehl, and Friedli 2018).

It emerges the need for a systematic understanding and synthesis of the possibilities that technologies and data availability open in the service field. A contribution can be made through taxonomies or classification frameworks regarding service typologies. The identification of critical characteristics and the definition of a specific overview on those services would contribute to the common understanding of the service solution and subsequently to the creation of them since it may help practitioners during the design phase.

5.2. Research direction 2

Even though several concepts related to the possibility to gather data and enable data utilization has been included in the research keywords, the specific focus of data remains poorly covered in the pool of paper, and mostly appears as an underlying enabler. From the technology analysis clearly emerge the use of data analytics is a fundamental step in the offering of this new service, but there is not a systematic understanding of the possibilities that leverage data creates in the service offering. Moreover, data alone does not provide interesting insight, services that rely on data analysis requires structured approaches to enable firms to transform data into information in order to offer valuable services to customers. Particularly mechanisms of service design through data analytics remains poorly covered in the pool of paper and lacks enough support in the literature (Zheng, Lin, Chen, and Xu, 2018; Kuhlenkötter et al., 2017). Furthermore, value creation mechanisms need to be integrated into service design since it is well recognized that the value creation and co-creation mechanisms are at the basis of the deployment of such solutions (Sambit, Vinit, and Joakim 2016). Indeed, sharing data represents a possibility for a high level of customization, configuration and implementation of solutions (Sambit, Vinit, and Joakim 2016), but needs value creation and assessment mechanisms need to be clearly identified to convince a customer to effectively share data (Ostrom et al., 2015; Rymaszewska, Helo, and Gunasekaran 2017) due to the conflict between the desire for privacy and personalization (Ostrom et al. 2015). Moreover, if the applications are into a business context, the need of a culture of trust with business partners, customer and users emerge more and more, since clients have no intrinsic interest in sharing operational data with machine tool contractor and to hook them up to their data gathering and processing systems (Kamp, Ochoa, and Diaz, 2016).

The lack of the overall comprehension of data-related services, not only concern their characteristics, but the overall development process. Analysis of value creation practices considering data related applications should be performed and the definition of structured approaches that enable firms to leverage data to create value, both for customers and internal applications, are missing. Moreover, processes to translate data into information and value to systematically develop data-related services should be formalized considering also to fill the gap that emerges between the technological perspective and the servitization perspective, providing tools and methodologies aiming at synergistically address both domains. Service Engineering methodologies may be proposed, considering including data-driven, co-creation practices, and industrial and technical lenses.

5.3. Research direction 3

Offering complex solutions to customers leads to a different interaction of actors with respect to the traditional offering and brings different mechanism of collaboration, coordination and value creation that need to be explored. A big challenge that is clearly emerging is the need for different competencies to work together (Ostrom et al. 2015), from technicians with new skills (De et al. 2016) to a skilled workforce to create value in data analytics (Rymaszewska, Helo, and Gunasekaran 2017) and in general multidisciplinary teams to solve complex problems (Demirkan 2015). Also, a new network of suppliers where information sharing is expected (De et al. 2016) is needed. Conducting the review, numerous pieces of knowledge have been found in the context of data analytics to support data-driven services on platforms. Nevertheless, these are scattered across different fields, such as computer science, electronic engineering, industrial engineering, and management. All applications included different competencies, and specifically product providers, service provider and software providers need to collaborate together to offer real value for the customer, underlying the multidisciplinary required when approaching digital servitization. Moreover, by introducing digital products that change customer process and allow the provider to gather data, learning from the client (Coreynen, Matthyssens, and Van Bockhaven, 2017) completely change relational paradigms, creating more closer and new customer relationships (De et al., 2016; Kamp, Ochoa, and Diaz, 2016). The entire ecosystem and cooperation mechanisms are changing and evolving, and the participation of different firms in the network may offer opportunities regarding access and sharing of resources, including knowledge and capabilities (Loukis et al. 2017). Additionally, even studies reveal how the information sharing among firms create the potential for collaboration that enables more efficient operations, as emerged both in CL1 and CL3, there are limited works that further investigate value creation mechanisms in a data-enabled ecosystem.

New cooperation and collaboration mechanism need to be analysed and conceptualized to support firms and all actors of the service network in this transition. The ecosystem perspective should be included considering access and sharing of resources, embracing knowledge, capabilities but also data streams. In particular, the digital ecosystem that characterizes the majority of data-driven services may be analysed from a platform perspective, that strongly emerges as the tool which supports data collection and analysis as well as application deployment, taking into account how the design of the technological architecture impacts the value creation for different actors.

III. DIRECT ANALYSIS OF INDUSTRIAL NEEDS

The presented research is concerned with the provision of contributions that would be mutually valuable from academics and practitioners, and it has benefited from an intense collaboration with industrial realities. The presented Chapter presents the collaborations that have been in place alongside the Ph.D. research, that are on one side continuous participation in the "digital transformation program" of ABB company, who also financed the research, and on the other a collaboration with the ASAP management forum, which enables short-term collaboration with several companies. The chapter explains how the two different environments supported the research and provide a deep analysis of challenges that have been identified in ABB, which subsequently led to the definition of research objectives.

1. Direct involvement in ABB S.p.a.

Throughout the PhD program, the author conducted action research, based on the principles of participant observation in ABB S.p.a.. ABB is a multinational pioneering technology leader in electrification products, robotics and motion, industrial automation and power grids, serving customers in utilities, industry and transport. The company operates in more than 100 countries with about 132,000 employees and infrastructure globally.

Recognizing that a fundamental step in taking full advantage of digital technologies is the integration between information technologies (IT) with operational technologies (OT) know-how (e.g. domain and process expertise), ABB has undertaken a digital transformation program, recognized under the name of "ABB Ability™". IT specifically identify telecommunications equipment focused on the storage, recovery, transmission, manipulation and protection of data. At the same time, OT are a category of cloud computing and communication systems employed to manage, monitor and control industrial operations with a focus on the physical devices and process they use. With the technological advancement and the increasing attention towards data-driven and remote operations, the two environments have started to converge to access real-time data, to interconnect facilities and also to deploy new solutions. Figure 16 reported the general overview of the concept from ABB point of view.

ABB Ability™ main components are described as follow:

- *ABB Ability™ solutions* represent combinations of products (a system) and/or services delivered via software & connectivity. These solutions should be built from common technology components at the device, edge, control and cloud level that from the ABB Ability™ platform.
- *ABB Ability™ platform* is the collection of standardized software elements in devices, gateways, and the cloud, that will enable ABB and its partners to develop highly scalable and integrated solutions with a consistent interface for customers.
- *ABB Ability™ cloud* is the common cloud, based on Microsoft Azure, combining ABB, Microsoft and third-party web services.

Theoretically, with the project maturity, customers and partners will be able to develop widgets, API or additional service on ABB solutions, enabling the platform to provide additional value.

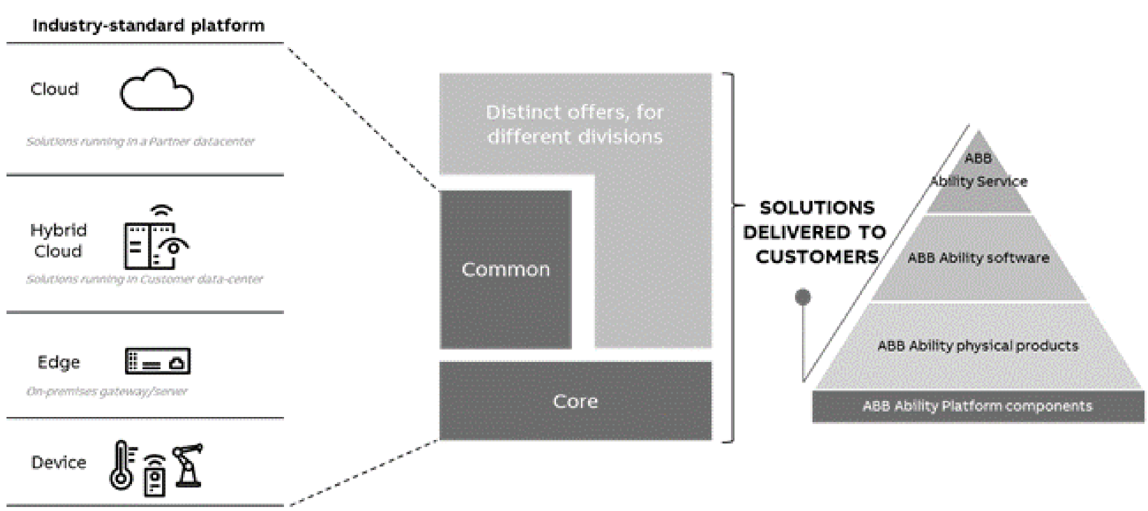


Figure 16 - ABB Ability™ overview (ABB website)

More specifically, during the three years, the author was regularly involved in the “business life” and everyday activities of the Cloud and Connectivity Team. This team is mainly responsible for the breakers Product Group, part of the Power and Protection business line, belonging to the Electrification division. During the three years, the organizational structure of ABB has changed, and the team becomes directly dependent on the division, in a specific organization dedicated to all projects regarding digitalization. The team has also acquired the responsibility to align all the digital initiatives into the Business line, that has changed into Smart Power. In this context, the author had the opportunity to focus on one specific *ABB Ability™* solution under development: the "*ABB Ability™ Electrical Distribution Control System (EDCS)*".

In particular, the focus of the researcher and the team in which she was involved was to understand specific applications that can be deployed to a customer as a service, leveraging the already existing infrastructure of hardware, connectivity and computing power. Figure 17 depicts the specific interest of the research, both in terms of the specific industrial application and in relation to the general architecture of a big data system.

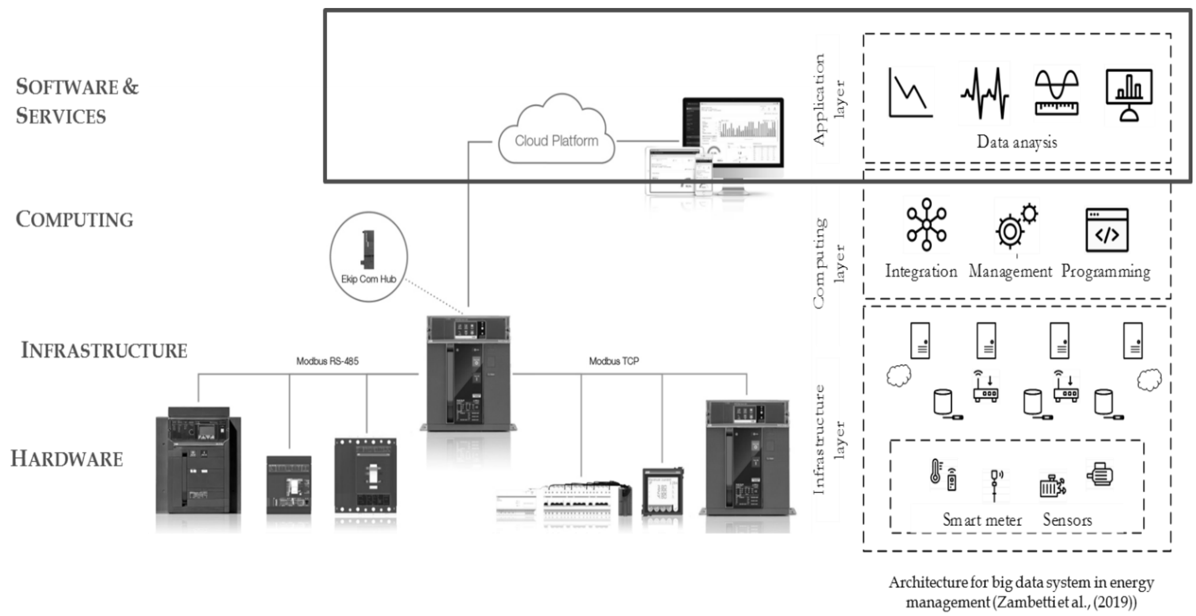


Figure 17 - Representation of the specific aspect under analysis (ABB website and author elaboration)

The researcher had the opportunity to take part in company meetings, understand the dynamics and the challenges of the company as well as to contribute to the development of the platform actively.

During the three years of research, the author specifically actively participated in the following activities:

i. Analysis of the actual data-driven service proposal;
ii. Market research;
iii. Analysis of customer requirement and needs;

iv. Definition of specific changes needed on the platform;
v. Analysis of internal requirements and needs;
vi. Participated in the process of convergence of different business lines ABB Ability Solutions into one same platform:
vii. Contributed to the ideation of new services and proposal of advancement in the platform;
viii. Development and evaluation of the offer conducting several pilot projects around the world;
ix. Collaboration with external companies working in the field of energy management;
x. Involvement in the QR code tracking project;
xi. Development and validation of the DDPSS SE methodology.

During the conduct of those activities, many people have been involved within the company from different business functions and departments ranging from product R&D to software developers, sales and marketing, service and operation management. Other business lines have been also involved along the course of the research since different products have been included in the same solution: as already mentioned, at the end of the second year of Ph.D. “*ABB Ability™ EDCS”* become an Electrification division project.
Moreover, different external partners have been in touch, both big companies, startup firms and consultant, that contributed in different ways to the development of the platform.
Overall, considering the main goal of the research project, the deep collaboration with ABB has enabled the researcher to:

i) Reach a consciousness state of the attitude of a big multinational company as ABB toward DDPSS implementation and transition;
ii) identify industrial practices and challenges that need to be addressed while pursuing data-driven servitization; and
iii) develop tools and knowledge that are actionable and can actively support practitioners.

Hereafter, a general understanding of the main criticalities from the industrial case, that consequently led to the definition of the research directions, is presented. Challenges have

been divided into "organizational" and "development" perspectives, considering on one side the issues that arise with the introduction of new service-oriented and interdisciplinary projects in a product-oriented company and on the other the issues into the realization of DDPSS. These challenges have been defined from the activities conducted during the three years of the PhD path, with observatory activities and action research.
These criticalities are specifically referred only to the business line and division interested in the research and reflected the novelty of the specific digital servitization project. Moreover, the criticalities mainly represent the initial state of the project since this analysis has been primarily carried out in the first year of the PhD. The considerations have also been updated considering the changes and enhancement that the company carried out in the three years, in which ABB is investing many resources in the improvement of digital offers, and it is focused on the development of successful solutions. Nevertheless, it has been decided to highlight the initial points and difficulties that needed to be overcome and that may be replicated (with specific contextualization) to other industrial realities that start a project like this.

1.1. Challenges of ABB towards DDPSS offering: organizational perspective

I. Product-oriented company are not entirely prone to service mentality and confidence in the digital process

The historical background of ABB is rooted in product-oriented solutions, they have an immense variety of offering in the market, and the highest percentage of income is strictly related to this part of the business. There are different service offering on the market, most of them related to maintenance and product retrofitting. New products launched in the market are usually based on "technology push" logic. The traditional product orientation and the technological leadership of the company lead to the selection of new offers and products. It is possible to notice their focus on the product also from the misalignment in the organization between service and product management. Most of the time, each business line has different groups dedicated to product and services, meaning that the PSS perspective is not wholly adopted internally. Often, different groups have divergent goals, but the one responsible for products has a more decisive influence on decisions. Service units functionally depend on a global service function that is trying to create cohesion among the services offered and the spread organization, while hierarchically, are under the accountability of the product organization.

Concerning digital solutions, another independent team has been created as an autonomous product group with the specific duty of management and development of the digital solutions only, and a dedicated R&D group is devoted to the implementation of software requirements. Within this group, some product managers are dedicated to communication protocols, gateways and other specific technologies that are needed to develop the solution infrastructure are also involved. Specific maintenance applications that are enabled by data availability are identified as service, so that are developed by the service group, which has to coordinate with the one responsible for digital solutions. The solution is generally proposed on the market from the same sales team as for the products, but recently the company has hired a specific group of people to train them and devote their effort to the sales of digital solutions.

II. *Complex organization reflect complexity for development, innovativeness and alignment between different divisions and business lines*

ABB Ability™ is a company project, which involves all ABB divisions and business lines, and requires a significant effort in the harmonization of offerings. Nonetheless, ABB organization strongly reflects the matrix business organization into divisions and functions, as well as the historical product orientation of the company. Even if during the three years of the research, a considerable effort from headquarters has been noticed considering harmonization goals, complete integration and collaboration among business lines are still not common to observe.

Effort in the digital offering is mainly originated from the business line as a bottom-up approach, limited communication among the business lines and divisions lead to the development of similar solutions, and the competitiveness between them lead, sometimes, to the impossibility to make the different solutions integrated to each other. This behaviour results in a consumption of effort from all the business lines without leveraging synergies. Indeed, business lines spend resources on similar projects with low or absent alignment and sharing of knowledge. Usually, when a business line can establish a solution that is stable and successful, the division may adopt it as a solution that goes to incorporate also all the others similar solutions of all the business line under the same division, requiring their harmonization.

1.2. Challenges of ABB towards DDPSS offering: development perspective

I. Difficulties in considering the customer perspective

One primary consideration regarding service offering relies on the identification of customer needs and involvement (Mont 2002); nevertheless, in ABB approach has been noticed an insufficient collaboration and involvement with customer. Specifically, for what concerns the digital offer, the collection of data has been defined before the definition of specific utilization both in the context of service offering and internally. The identification of new solutions has usually relied on successful services or solutions implemented by competitors and boasting a fair market share. Moreover, ABB is used to listen to customer preferences and requests after the definition of new solutions to refine the concept, collecting feedbacks through direct interaction during visits, without specific procedures. In the same way, also the EDCS project is conducted. Moreover, customer segmentation had been initially defined as the one already defined for products, creating challenges in understanding real customers and resulting in a wrong customer segmentation for what concerns the digital solutions, since it should have been done differently from the one for products. The insufficient comprehension of customer needs and few rough ideas of the final users of the solution and the information they needed, led at the beginning to a consequent development of a solution that was not exactly fitted, and to the development of value propositions that were not shared from the customer perspective.

II. Internal competencies, resources and structures are under development

Generally, the company is still in its infancy for what concern digital solutions and the creation of internal competences is a process that ABB is still undertaking. The main lacks for what concern the ideation of valuable services are related to the data analytics domain and to the contextual domain in which the company wants to enter. On one side, data analytics possibilities are not handled at their full potential, both due to a lack of resources able to analyze a large amount of data, and an incomplete understanding of what analytics tool may perform in the context of service and data transformation into information. On the other side, the possibility to gather data opens up the possibility to develop services related to the energy flow, energy costs, certification and more broadly, customers operations. Nevertheless, the company do not historically own the know-how on those topics and needs to acquire or integrate a great part of it in order to figure out actionable solutions for customers.

Considering resources, ABB can rely on good budgets for investments and consultancy projects: the company is constantly working on developing new competencies leveraging cross-fertilization between different organizations and between different figures that belong to different ABB internal companies. Nevertheless, human resources are still limited for platform development and requirements implementation; indeed, even working with an agile development approach, it results challenging to satisfy them in a short time. To overcome this challenge, the company is recognizing the need to enlarge the platform development team. Moreover, the definition of priority in the implementation followed feasibility parameter and the product manager insight, besides the lack of competences and customer involvement sometimes led to the development of features that do not work correctly because of a wrong interpretation of the domain or that are not useful for the customers. To avoid this, ABB is now structuring a prioritizing approach for all the platform requirements, that should take into consideration also the potential value that implementations have for customers.

Furthermore, the company recognized the importance to have a dedicated team that could be able to support customer for problems related to the platform itself, communication and security issues and so on, that was not present and is now under development. A final consideration is that the company is also starting to organise in order to leverage data availability internally. Indeed, considering that the platform will generate a lot of data that can be used internally, both from the service team, but also form R&D, sales and marketing team and so on, some ideas are now emerging on how to structure the back-end for "internal customer" and on how to organize internally to deliver services based on data monitoring at service provider side.

III. Lack of procedure or methods to engineer the information and service components

As already stated, ABB started collecting data in the wave of its strong position as a technology provider, which opened up the possibility for extensive data collection initiatives. Thanks to these initiatives, the need for a stronger focus on the final scope for which data is collected emerged. At the same time, ABB figured out the necessity to devise more specific procedures, methods and tools to support the ideation and design of new services and solutions, which clearly need to be differentiated from the ones adopted for products and traditional services (i.e. retrofitting and maintenance). Indeed, concerning the different parts that composed a DDPSS, the need to design suitable methods for the engineering of the service and information components has been observed.

IV. Difficulties in communicating the value of a solution to the customer and, consequently, customers are reluctant to share data

Given the strong tradition in the product business, evaluation of benefit with respect to internal expectations and customers are intensely focused on monetary impacts.
This focus is leading the company to struggle in the assessment of the value for the customer in the implementation of EDCS solution relying on standard investment evaluations metrics such as the Return of Investment (ROI). Nevertheless, in the context of a digital solution is not easy to define economic benefits, especially for data analytics applications: benefits from customers can be achieved by implementing some decisions based on the data that are provided by the platform, which means that no economic benefit is directly associated with the platform, but the indirect ones can be multiple, e.g., the value of avoiding other risk and possible losses should be evaluated. The value that can be deployed to the customer may also change during time, with respect to contextual conditions. Moreover, even within the same customer segment, the application can be different and broad and each of them can have a different economic value. This means that establish a standard evaluation of the implementation of a solution is hardly reachable.

For what concern internal evaluation of benefit, again, a standard economic approach is not worthily: indeed, there are different dimensions to consider. For example, one of the significant potentials of having connected devices is to understand where the installed base is, that is information that until now the company does not have. Moreover, understand how customers are performing may help to create other revenue streams from different services, such as an active and active proposal for maintenance or replacement.

V. *Difficulties in developing a standard solution*

The general aim of “ABB Ability™ EDCS” is to provide a standard solution that can be deployed to different customer segments. The platform has a modular architecture, and it is constituted from different feature and specific application can be activated by the customer accordingly to his preferences, giving them the possibility to configure the platform as they think is better for their own needs. Nevertheless, the same problems in different customer segments can require different information to support decisions or completely different solutions. Some variables may also change between customers in the same customer segment, and deploy standard application results difficult. Moreover, ABB is a company that has a worldwide focus, and this creates discrepancies also on external and contextual factors that may be different from one country to another.

VI. Need to understand and manage network changes

Thanks to the connectivity of product, new relationships with customers are unintentionally created: the service provider can understand where their products are operating, how they are operating and, in some cases, also enter the customer operation field thanks to the aggregation of different source of data. This implies that the customer and the service provider are in direct contact, that is not the usual relation that ABB has with customers. This situation leads in some way to bypass another actor, like local services, local sales but also distributor, consultants and panel builders.

The digital solution may also require the implementation of new services with actions at the service provider side; nevertheless, ABB is not structured to manage such a huge amount of relations. This means that, for example, to deliver services based on real-time data, ABB should structure different platform interfaces to deploy to intermediaries or local service structures to deliver a final service to the customer.

From a broader perspective, new collaborations are also taking shapes with both new technology partners that enable all the infrastructure needed to implement an IoT solution and on the applications side, where it is recognized the possibility and the need to integrate other players in order to create synergistic applications and offers. If on the technological side, ABB has is already well structured and several partnerships are in place, on the application and service side, first steps are now taking place.

As a summary of what observed, it can be stated that also in ABB context, the servitization is still emerging. Besides the company is working hard to identify new business models and opportunities, services and products are not yet integrated into a unique trend. Moreover, digital advancements are challenging the company from several sides, and the company is still trying to adapt its capabilities and skills to the DDPSS offer, lacking a comprehensive understanding and structured approaches thought DDPSS development. This exploratory analysis led to the identification of field needs and difficulties into the successful realization of DDPSS. The main criticalities identified have been compared with the gaps that emerged from the literature review reported in chapter II, and have been used to identify a research path able to adequately addresses both the academic and practitioners' domain.

2. Collaboration with ASAP Service Management Forum

From the end of the second year, authors also join the ASAP Service management forum, which is an Italian organization that has the aim to gather service management and servicing community for various activities such as research, training, networking and knowledge transfer, within the product-service system domain.

University research centres of Brescia, Firenze and Bergamo and industrial and service companies collaborate for innovation in the design and management of services, for the strategic development of the "service business" and the management of change that directly comes with the introduction of service offers.

The author collaborated with them contributing to the stream of research “Servitization goes digital”, and actively participate in community meetings, workshops, focus groups and networking activities. She also had the possibility to leverage the community to research activities, explorative analysis and framework validation. She was responsible for a focus group launched named “Data to Value” were specific interviews on DDPSS topic have been carried out to several companies working in different application fields, at different maturity level on their servitization path and into different positions in the service network.

The collaboration provided the possibility to compare one, even rich, reality of ABB, with the experience and competences of multiple and various other companies that are undertaking the same process of Data-driven Servitization.

IV. THE RESEARCH

This research is devoted to the study of the process of Servitization, as it is defined in chapter I, enabled by data availability and related technologies, with a specific focus on industrial DDPSS, which comprise both hardware solutions, software, data as well as an indispensable service component. As already understood, one of the primary growth potentials in the wave the fourth industrial revolution is recognized in the paradigm shift from a traditional product orientation to the provision of bundled solutions (Kamp, Ochoa, and Diaz 2016). The impact of digital technologies is going to transform radically the way firms operate, configure, interact and create value towards service offerings (Coreynen, Matthyssens, and Van Bockhaven, 2017). Those changes can pose several challenges to firms, operating in either well-established or young industries. Even though prior servitization research has explored the "Digital Servitization" topic (e.g., Schroeder and Kotlarsky, 2014; Vendrell-Herrero and Wilson, 2017), the links between Industry 4.0 and digital technologies with servitization transformation are still under-investigated (Paschou et al. 2018; Frank et al. 2019). The importance of better understanding this transformation is highlighted in different works (Parida, Sjödin, and Reim, 2019; Tronvoll, Sörhammar, and Kowalkowski, 2020). Moreover, understanding how to use information effectively in enabling and supporting Servitization is still limited (Cenamor, Rönnberg Sjödin, and Parida 2017) as well as research on how to create and share value within the new ecosystems (Sklyar, Kowalkowski, Tronvoll, and Sörhammar, 2019).

This chapter aims at highlighting the specific scope and boundaries of the research, as well as explain the research design and procedures applied to achieve results. Research objectives and questions will be detailed defined in the first section of this chapter, then the research structure and methodologies are described in the second one.

1. Research scope

The general scope of the research has its roots in the identification of crucial challenges in practical settings as well as from theoretical deficits. Chapter II illustrates the analysis of the current state of the art in available literature representing Servitization and the adoption of Industry 4.0 data-related technologies. Chapter III reported the main challenges that have been identified during the three years of research from the practitioner point of view, in the path of the successful achievement of DDPSS. Comparing the emerging trends and gaps with the necessities and needs that emerged in ABB company, it is possible to define similarities and convergences which, together, lead to the consciousness and willingness to pursue the research scope. Indeed, the research has been devoted explicitly to three defined focuses, which are (1) the characterization of DDPSS, (2) their development and (3) the considerable changes that they create in the value chain. The motivation of the research is to provide actionable means to practitioners working in the DDPSS domain, contributing to the successful solutions to practical problems by means of knowledge generation.

A more detailed definition of research objectives and questions is provided hereafter.

1.1. Research objectives and research questions

Considering the high-level research aim, which pursues the development of comprehensive, in-depth knowledge and understanding of the value of data availability (enabled by Industry 4.0 technologies such as big data analytics, cloud computing and IoT) in the context of PSS, the specific research objectives have been then defined in this phase. Particularly, it was possible to identify the contribution that the research intent to cover, analysing and combing the gaps that emerged from the literature with the needs gathered in ABB and other companies.

Although some new streams of research are now emerging on “data-driven” services, a common agreement on the definition of what those services are, is still missing and literature on this topic is widespread among different streams and disciplines (Klein, Biehl, and Friedli 2018). The technological advancement in product connectivity led to the offering of complex solutions rather than traditional PSS, and companies often wish to extend service, but lacking the knowledge about the possibilities that data analytics can provide in the context of those new services. The links between digital technologies and servitization transformation are still under-investigated (Theoni Paschou et al. 2020) and the importance of better understanding the transformation is highlighted (Parida et al., 2019; Tronvoll et al., 2020).

Those technologies are facilitating the generation and transmission of relevant data along the entire PSS lifecycle. However, one main concern is that data alone does not create a competitive advantage, most of all in the service system context, where the intrinsic purpose is delivering value to customers, satisfy specific user needs and build the long-term value of the relationships, rather than performing short term transaction executions, which can also be easily supported by automated information systems. Besides notable cases and several studies that recognised the potential of data into the service domain, the understanding of how to effectively use information in enabling and supporting Servitization is still limited (Cenamor, Rönnberg Sjödin, and Parida 2017) and only fragmented knowledge on how to systematically develop them and translate data into information exist (Anke 2019), especially considering B2B applications and data gathered form product and sensors at customer location. Companies are struggling to create new solutions and usually handle them with traditional approaches, often linked to product and software development.

The growing digital disruption across industries and ecosystems is also altering boundaries and changing established firm interdependencies and network positions, challenging value-creation and revenue-generation with new opportunities (Sklyar et al., 2019). As a consequence of the development of a DDPSS, the firms' network is evolving into even more complex and dynamic structures and collaborations, which can take place internally between engineering and management, with the customer as well as in the form of cross-company collaborations (Platform Industrie 4.0 2019). However, the shapes and the possibilities that such network composition enables are still emerging. The challenges for companies are to understand the value of data, the interplay of stakeholders' perspectives as well as the different characteristics of value along the lifecycle, in those complex ecosystems.

In light of this, the research focuses the effort on the identification of how the data availability can affect the definition of the PSSs offering and their development. Indeed, after the SLR on servitization and data-related technologies, the attention has been devoted to two of the gaps that emerged, that are, respectively, the characterization of

DDPSS and the Service Engineering (SE) process needed to develop DDPSS, as summarized in Figure 18. Those two focuses also consider the inclusion of the ecosystem perspective, reflecting both the reshaping of the companies' network and value creation possibilities.

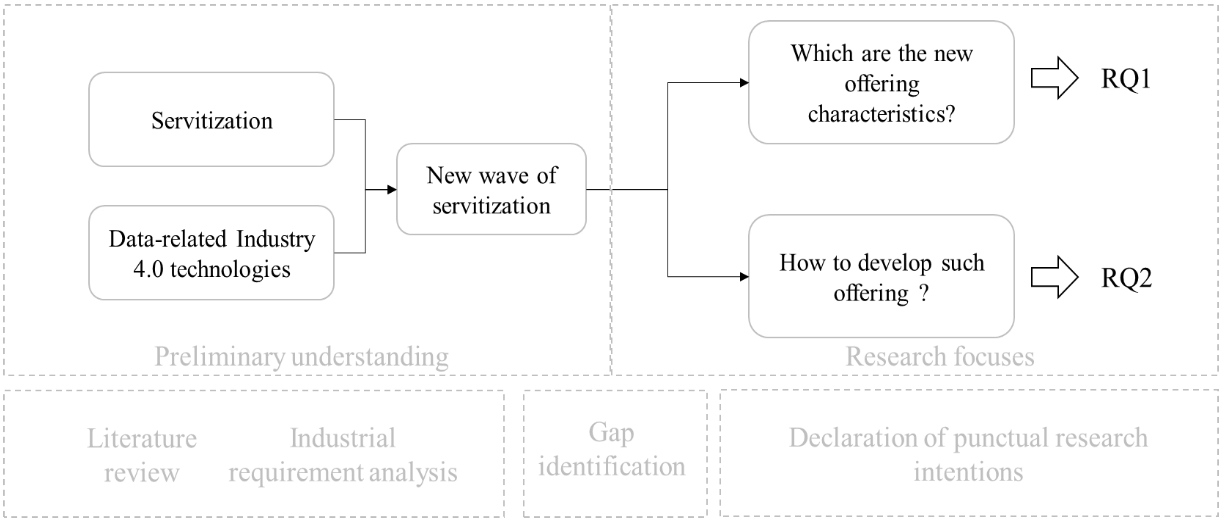


Figure 18 - Research focuses

In order to provide a structured contribution, the main research questions guiding this research has been formalized as follow:

RQ1: Which are the characteristics and specific features of DDPSS that differentiate them from the traditional PSS?

As shown in the literature review, DDPSS is an innovative concept with respect to traditional services. Nevertheless, a clear and complete landscape of the emerging possibilities is still missing. **There is the need to comprehend those new offers deeply and to generate order and synthesis on the actual state of the art defining the specific characteristics they have**. This holistic picture would also support manufacturers and academies to understand which new approaches are needed to overcome challenges.

RQ2: How is it possible for a manufacturing firm to move from data acquisition, enabled by the integration of sensors with products and by connectivity, to DDPSS offerings?

Data exploitation is recognized as a new source of value in service offerings. However, research on this emerging trend is still at the beginning, and additional studies are required. Given the current state of the art, **there is a need for structured approaches that can lead companies to extract valuable information from data gathered from products**. Moreover, there is no clear **methodology focusing on the integration of data gathered from product and sensors in a PSS**, and studies on the **design of new product-service concepts using those data systematically** are rare.

In order to better clarify the interest and the positioning of the research, the two RQs have been also set into the theoretical framework developed by Baines et al., (2017), which represents a holistic view for the study of organizational transformation towards Servitization. As represented in Figure 19 RQ1 is related to the general context of change and investigates the impact of external forces as technology advancement and industrial behaviour. It aims at giving a descriptive overview of what is happening in the domain. RQ2 concern the process of change, considering models and techniques that enable manufacturing firm to undertake the successful implementation of DDPPS, both analysing current practices but also proposing a comprehensive SE methodology.

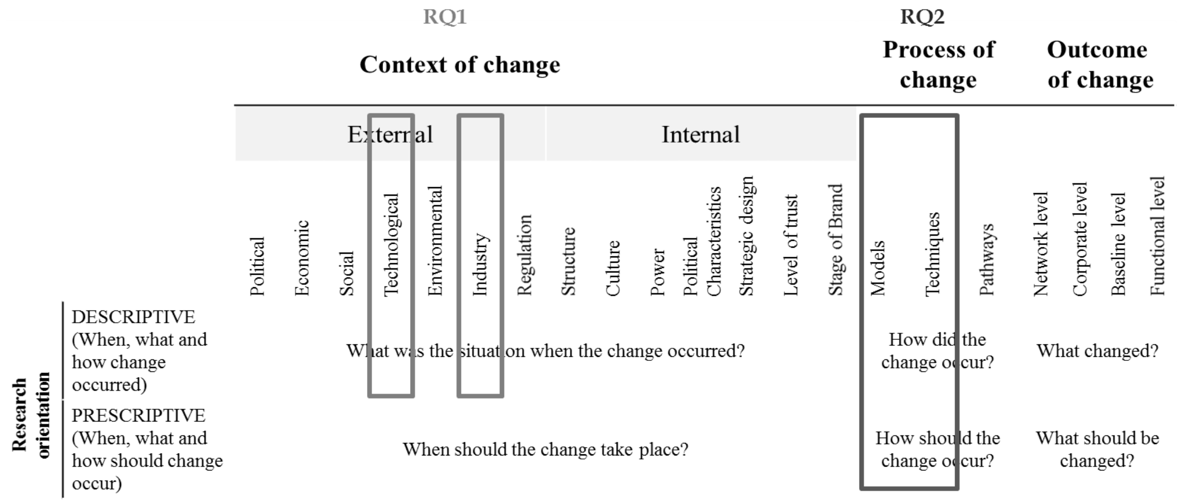


Figure 19 - Positioning research questions in the reference framework by Baines et al., (2017)

2. Research design

The research is based on practical problems and experiences by practitioners in the manufacturing industry, and as many pieces of research in operations management, this work digs into the academic literature. The overall study is characterized by continuous interaction between the practical and the conceptual worlds, with a theory-building approach. To answer the RQs and provide actionable answers to the needs of practical relevance and academic contribution, the underlying research process consisted of an iterative learning process following a circular path as depicted in Figure 20. This continuous and iterative conversation in applied theory construction, between knowledge and experience of the phenomenon that is the focus of the theory, facilitates the accumulation of relevant and rigorous theoretical knowledge of the phenomenon (Lynham 2002).

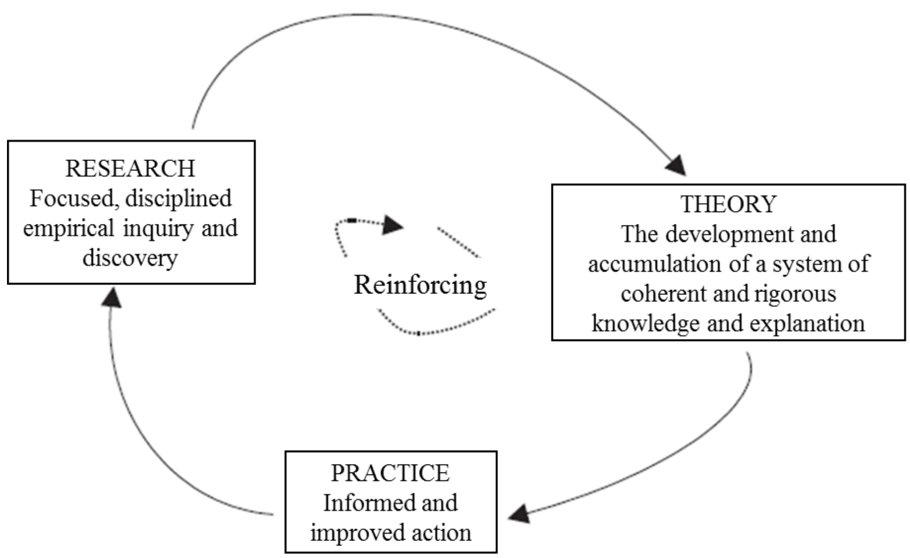


Figure 20 - The Growth Cycle of Applied Theory-Building (Lynham 2002)

2.1. Research framework

Figure 21 shows the research framework leading this research and describes its structure. It can be used to make the study and its contribution more tangible and more comfortable to communicate with practitioners. The project rooted in the definition of an area of research that has been intensely investigated in the literature and pursued a parallel collection of information for the industrial domain. Those steps guided the identification of research questions that have been answered through different paths enabling the author to contribute to a piece of knowledge.

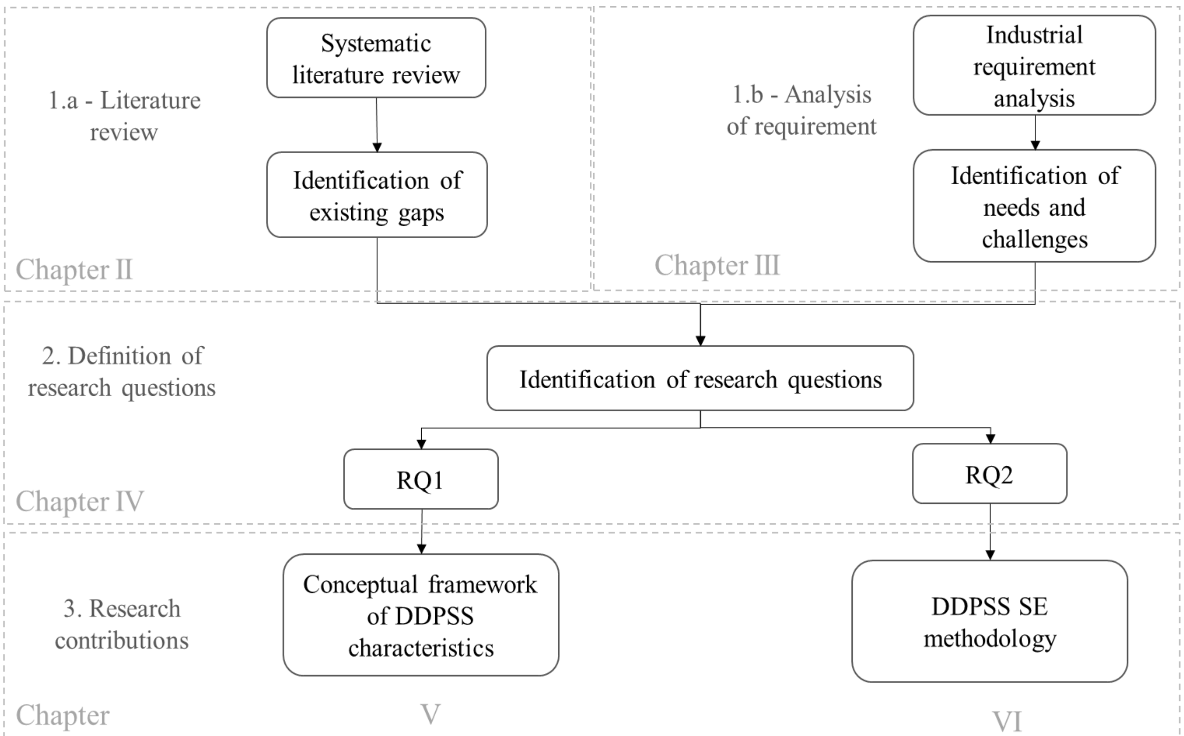


Figure 21 - Research Framework

As represented in Figure 21, three main phases constitute the research:

1. **Literature review and analysis of requirements.** Aiming at contributing both to practice and theory, the first phase is subdivided into two parallel and synergic investigations on the topic, considering both the state of the art in the academic field and the practitioners' needs and point of view. The work had been structured from the beginning with a twofold analysis, considering the importance of an extensive literature analysis on the PSS domain end Industry 4.0 technologies related to data and a specific analysis of the leading industrial requirements settled in collaboration with ABB. This phase is deeply discussed in chapter II and chapter III.
2. **Definition of research questions.** The exploration of the research gaps and practical needs in the domain enabled the researcher to compare, investigate similarities and consequently identify a specific research goal and two main research questions to be

covered in the academic and in the industrial domains. Two RQs have been defined in Section 1.1.

3. **Research contribution.** After the identification of main RQs, specific methods and suited approaches were identified for each of them. Application of methodologies, grounded in the research context, enabled the researcher to identify two different artefacts that represent the answers to the questions. Those artefacts have also been validated in other ways considering every time the one that better fit with the problems. When possible, the validation phase has been performed in collaboration with ABB as the main stakeholder, but applications were additionally pursued in heterogeneous industries to extend the applicability and generalizability of the method.

   RQ1 concerned with the development of a conceptual framework that has been based both on deductive and inductive reasoning. Research started from assumptions rooted in the literature analysis and; as the research proceeds, the assumption takes shape. Hypotheses generated have continuously been verified by comparing conceptualized data, with recurring validation with the industrial domain, with multiple case studies. In the end, a two-hierarchical framework representing DDPSS typologies based on different characteristics have been formalized. The contribution is better described in chapter V.

   RQ2 involved the development of a SE methodology dedicated to DDPSS. The methodology has been based on an affirmed SE methodologies, which is the SErvice Engineering Methodology (SEEM) (Pezzotta et al. 2014) and considers needed changes under DDPSS peculiarity given industrial requirements that originated in the context of the action research. Discussion with practitioners and applications within the action research setting were carried out to prove the validity of the proposed methodology, which is described in chapter VI.

   Ultimately, even not explicitly addressed in one of the research questions, another significant contribution of the research belongs to the pathways in the context of change, since along the industrial investigations several contributions regarding the individualization of firms' challenges, barriers and practices are provided in chapter III.

2.2. Research methodologies

The different phases of the research have been addressed through the application of different methodologies, mainly belonging to qualitative research. Creswell (2014) defines qualitative research as "*an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The process of research involves emerging questions and procedures, data typically collecting in the participants' setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of data*"(Creswell 2014).

In the following, the main research approaches are briefly explained in relation to the purpose of this thesis, while specific details on the activities and phases carried out are also reported in the dedicated chapter. Figure 22 shows the utilization of the different methodology along with the research framework.

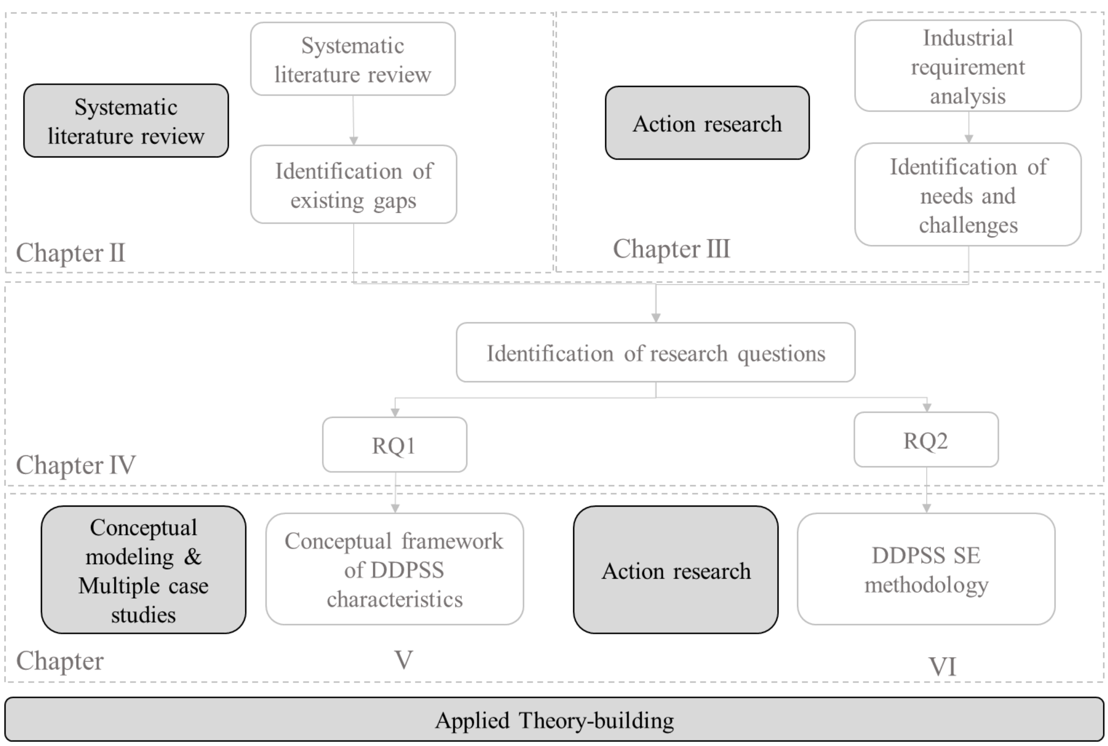


Figure 22 – Methodologies applied along with the research framework

2.2.1. Systematic literature review

A systematic literature review has been adopted as the first step to explore the topics under investigation and to bring up the emergent needs and gaps at the boundaries of the technological Servitization domains. This initial analysis helped to establish the legitimacy of the research and to clarify the contribution of the presented thesis. The systematic literature review is widely used to investigate the advancement of a specific stream of research as well as to propose recommendations for future studies (G. M. Goodwin and Geddes 2004). A systematic review can be distinguished from different types of publication for its scope and rigorousness. Indeed, a rigorous scientific investigation follows a specific, explicit and, therefore, reproducible methodology and approaches to identify, collect, evaluate and discuss relevant issues on the particular topic (Richard J and David B 1984) limiting bias and random errors (Cook, Mulrow, and Haynes 1997). Approaching systematic literature review requires a specific protocol, for several reasons:

(1) Potential issues can be anticipated and mitigated thank to the accurate plan;
(2) The plan has to be done before starting the review, enabling others to replicate the same method and evaluate its validity;
(3) Subjective decisions on inclusion criteria and data extraction are avoided.

The critical evaluation of the available literature supported the definition of scope boundaries and constraints of the analysis and helped in developing skills and capabilities for the critical assessment of scientific research. Concerning each research question, more narrow-focused literature reviews were carried out for each specific topic, as reported in the dedicated chapters.

2.2.2. Action research

In parallel with the literature search, an action research approach was conducted as an underling methodology following all the research paths. Indeed, as it is possible to better understand in chapter II, the author was hosted for three years in ABB company, working in a deep relationship with the team responsible for the process of digital Servitization.

Action research may be defined as a process in which "*applied behavioural science knowledge is integrated with existing organizational knowledge and applied to solve real* *problems*" (Shani and Pasmore 1895) and aims at contributing both to the practical and immediate problematic situation of practitioners and to the goals of science (Rapoport 1970). Action research differentiates from other methodologies for the following characteristics (Gummesson 2000):

i. Action researcher takes action: he/she should directly work in a real organizational system, and the research directly contributes *to* action, rather than be *about* action;
ii. Is interactive and participative: Action researchers need to collaborate and be members of a group, community or organization that together co-research;
iii. Concurrent with action: the researchers should take part in changing or improving actions on a system to solve a problem.

Since action research can include all types of data gathering methods (Gummesson 2000), qualitative tools such as interviews and focus group have been carried out during both the company requirements collection phase and verifications, with ABB employees, customers and partners. Generally, interviews were managed as semi-structured interviews following a specific set of questions that change according to the goal.

Moreover, the presence at many internal meetings and workshops led to an extensive collection of information, where the researcher became part of the organization and was exposed to a learning process on how situations are usually managed, and decisions are taken. Dezin, (1989) defined participant observation as "[···] *a field strategy that simultaneously combines document analysis, interviewing of respondents and informants, direct participation and observation* [···]." Data collected during those participant observations have also been verified through triangulation with different people in the organization to ensure the veracity of the interpretation.

In this setting, the preliminary understanding of challenges and needs was fed with data from practitioners and the longitudinal process of observation, participation and analysis, enable the researcher to verify and refine development and contributions iteratively. The investigation carried out in ABB, allowed the researcher to support the company in its specific process transformation towards DDPSS, contributing to the general understanding of those services, their development phase and the ecosystems and value creation structures.

Those results also enhanced the general knowledge proposing framework and methodologies that may be adapted in different contexts. Indeed, even though action research is an approach that may lack of generalization and of the possibility to be transferred to other situations, since the researcher is focused on a specific and contextual dependent situation (Checkland and Holwell 1998), this risk has been mitigated during the research with the collaboration of different companies, approaching the digital servitization path and operating in other contexts, by mean of workshops and multiple case study.

2.2.3. Qualitative case study and interviews

Case research has consistently been one of the most powerful research methods, and a more significant employment of field-based research methods has been called to cope with the growing frequency and magnitude of changes in technologies and managerial procedures (Lewis 1998). In accordance with Yin (1984), a case study can be defined as an "*empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not evident; and in which multiple sources of evidence are used*".

Additionally, as suggested by Scapens (1990), case study results in an appropriate methodology in the following cases, that matches this specific research:

- The objective would like to define current practice;
- The intent is to illustrate new and potentially innovative practices that particular organization are adopting;
- Examines the difficulties in implementing new procedures and techniques in an organization and evaluate their benefit;
- Explore certain phenomena and try to understand them within a certain context.

Building on understanding built up in ABB and with literature, additional case study research was conducted to refine the view on DDPSS characteristics and challenges and provide a holistic picture in the form of a descriptive model. In this research, a multi-case study is used to validate the framework developed in the RQ1. Results of cross-case lead to the possibility of generalization to support a broader pattern of conclusions than possible from any single case study (Yin 1984). Eisenhardt (1989) states that to do this data can be grouped into categories or dimensions so that a researcher can look for within-group similarities or differences between these groups. Within the case studies, the researcher mainly performed semi-structured interviews to deepen understanding (Mayring 2000).

To perform reliable case research, several precautions have been taken. First of all, the cases selection and sampling has been based on replication logic, considering only relevant cases to the conceptual frame and research question and including either case that will have led to the prediction of similar results or produced contrary results for theoretical reasons (Voss, Tsikriktsis, and Frohlich 2002). Moreover, heterogeneity in the application field of the different companies has that settled as a requisite, to enhance generalizability.

Interviews have been based on a structured protocol (Voss, Tsikriktsis, and Frohlich 2002) developed on the basis of the framework and all interviews have been carried out form two researchers, who both performed the transcription of the audio files to written text for further analysis. After the transcription, all the information has been matched and internally discussed to avoid the inclusion of subjectivity. The results have been also discussed with each of the company personally and later cross-case results have been debated with all the companies and a team of experts in the field of servitization.

2.2.4. Conceptual modelling

Along with case studies and action research methodology, theory-building through conceptual models and frameworks approaches have also been applied. The conceptual framework presents an integrated way of looking at a problem or a phenomenon (Levering 2002), describing the relationship between the main concepts that emerge. The conceptual framework can be defined as a construct in which each concept plays an integral role. (Jabareen 2009). Indeed, it "lays out the key factors, constructs, or variables, and presumes relationships among them" (Miles and Huberman 1994), and it provides an understanding of a phenomenon through the interpretation of intentions (Levering 2002).

Conceptual frameworks, for their nature, are usually developed through qualitative analysis of empirical data coming from different sources. They require a systematic synthesis of findings across qualitative studies, to generate new interpretations for which there is a consensus within a particular field of study (Sandelowski, Docherty, and Emden 1997).

With the aim of answering RQ1, the researcher developed both a narrative and a graphical representation of DDPSS, showing the key dimensions that concur in the service provider and the relationships between them, into a two-hierarchical conceptual framework.

V. DATA-DRIVEN PRODUCT SERVICE SYSTEMS CHARACTERISTICS

1. Objectives

As already stated in the introduction, DDPSS is an innovative concept with respect to traditional services. Besides the fact that they remain focused on some traditional principles, such as intangibility, value co-creation, innovative business model etc, they differ in several aspects, in particular:

- The service scope is expanding, covering not only the product itself but entering into the customer reality and including complimentary services;
- The product loses its centrality and can be seen as part of a whole complex solution;
- The presence of data flows needs to be managed, both considering its translation into information and insight and visibility policy between actors;
- The strong presence of software and cloud-based environment that were not present before;
- The value creation mechanism became more complex and include new actors.

Although some new streams of research are now emerging on “data-driven” services (Cenamor, Rönnberg Sjödin, and Parida, 2017; Lim, Kim, Kim, Kim, and Maglio, 2018; Mittag, Rabe, Gradert, Kühn, and Dumitrescu, 2018), a common agreement on the definition of what those services are is still missing. The literature on this topic is dispersed among different research areas and disciplines, as has been possible to notice from the literature review presented in chapter II. Hunke and Engel (2018) clearly stated the need to investigate data and analytics-based services in order to explain their essential components and few works has been found in this direction. For example, a conceptual framework has been proposed to explain the convergence of Servitization and digital transformation of product firm, resulting in nine different possibilities matching three incremental levels of digitalisation and three service typologies: i.e. smoothing services (the service complements the product without altering the product functionalities), (ii) adapting services(the service significantly expands the functionality of the product) and (iii) substituting (the service replaces the purchase of a product) (Frank et al., 2019). Another research presented a data-driven business model framework, considering six key dimensions that are commonly found, among various authors, in the business model domain. (Hartmann, Zaki, Feldmann, and Neely, 2016). Nevertheless, those works have been performed with a different focus with respect to the one proposed in this thesis; indeed, none of them represents the possible configuration and characteristics that the DDPSS have.

In this context, where limited research is devoted into the definition of the unique characteristics of those services (Klein, Biehl, and Friedli 2018) and only fragmented knowledge on how to develop them systematically exists (Anke 2019), this chapter aims at giving a first attempt in the systematic definition of data-driven services features and into the creation of a comprehensive framework that is able to describe DDPSS typologies. The main scope is to satisfy the necessity to understand those new offers deeply and to generate order and synthesis on the actual state of the art defining specific characteristics they have, covering the first gap defined in chapter III (Figure 23).

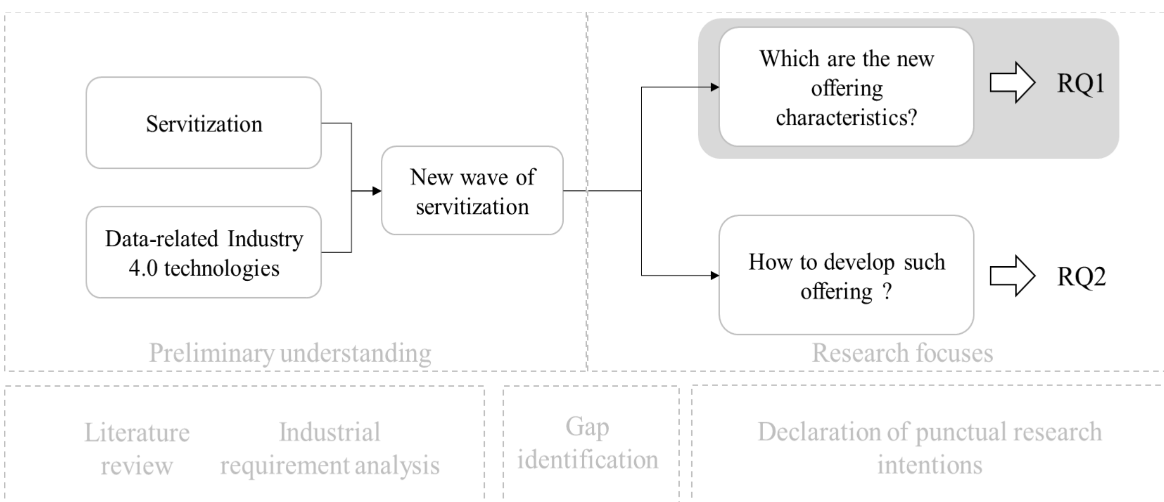


Figure 23 - Contribution of the presented Chapter in accordance with the identified gaps

The framework also resulted in a tool able to support the initial development of future service idea, mapping the actual offer of a company and try to cover all the areas not considered yet. Nevertheless, the framework remains a descriptive tool, following the predefined aim, able to represent DDPSS offering and it does not represent a prescriptive tool, considering that it does not take into consideration managerial and feasibility implication to develop new solutions.

2. Methodology

To accomplish the prementioned aim, classification methods, and specifically taxonomies and typologies, are the most adopted tools in PSS domain. Indeed, several authors proposed classifications of servitization strategies and PSS, aiming at providing clarity on the different possibilities that the service offering allowed (Martinez et al. 2017). Specifically, taxonomies and typologies should rigorously differentiate for the development procedure that in the former is empirical while in the latter is conceptual (Bailey 1994). However, the two terms are often used interchangeably in the literature, considering that several times both two approaches are also used in their definition. In this work, a conceptual framework has been developed on recurring and crucial DDPSS characteristics, that interrelated together are able to describe six different DDPSS typologies, that may be replicated at three level of service scope, as it will be extensively discussed in Section 3 of this chapter.

Conceptual frameworks, for their nature, are usually developed through qualitative analysis of empirical data coming from different sources. They require a systematic synthesis of findings across qualitative studies, to generate new interpretations for which there is a consensus within a particular field of study (Sandelowski, Docherty, and Emden 1997). The framework has been developed with a discovery-oriented, theory-building approach (Lynham 2002), reported in Figure 24, adopting a theoretical lens for the deductive reasoning and using multiple case studies to refine the framework inductively, in a recurring cycle that continuously complements theory and practice.

The author initially gathered relevant literature on the topic and analysed it in order to define specific categories and characteristics of DDPSS. With those categories, a first draft of the conceptual framework was initially developed, representing the first model to be improved. After the framework consistently represented those initial insight, it has been refined and verified with direct interviews with different companies offering DDPSS in the B2B domain.

Iterative and recurring steps have been performed during all the research, alternating between deductive and inductive processes. In the end, an additional case study has been performed to demonstrate the applicability of the final framework.

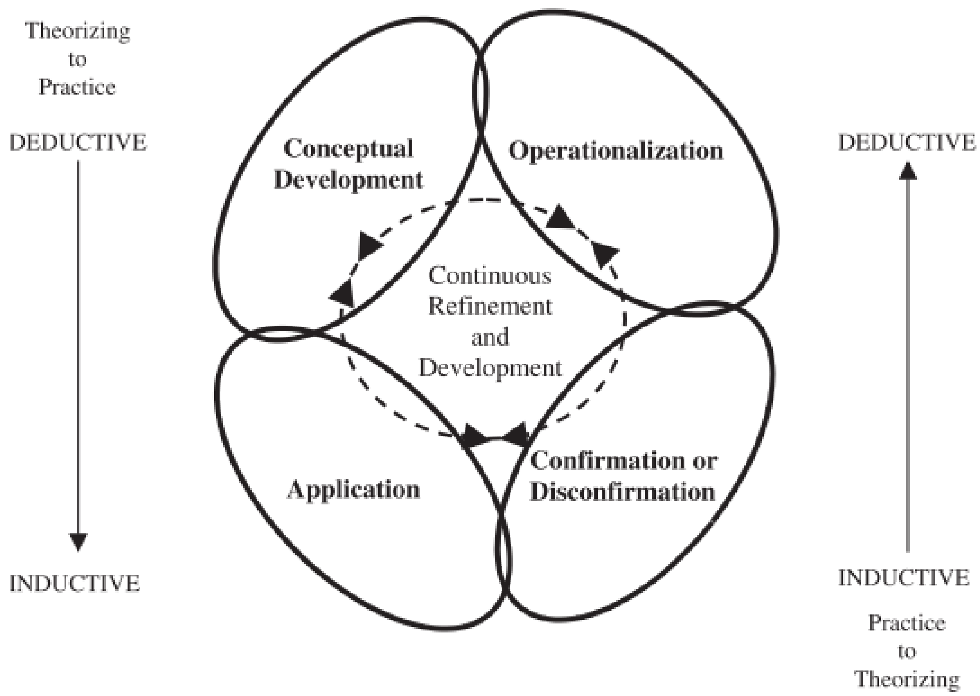


Figure 24 - The General Method of Theory-Building Research in Applied Disciplines (Lynham 2002)

A more detailed description of the main phases is reported:

i. *Literature analysis and identification of distinctive characteristics.* As an initial phase, a literature analysis has been fundamental to understand the current state of the art and to identify main gaps in the smart service, data-driven service and PSS topics. As already emerged, the need to reach a common view and understanding of the DDPSS phenomena is clearly stated (Hunke and Engel, 2018). With this purpose, during the literature analysis, attentions have been focused on recurrent o critical characteristics of those DDPSSs. Those characteristics have been subsequently organised into four dimensions.

ii. *Theory generation.* All the considerations regarding the dimensions and their relationships have been transferred in a two-hierarchical conceptual framework, which represent the model of this work. A conceptual framework has been chosen as the best way to develop our scope since it presents an integrated way of looking at a problem or a phenomenon (Levering 2002), describing the relationship between the main concepts that emerge. The conceptual framework can be defined as a construct in which each concept plays an integral role (Jabareen 2009). Indeed, it "lays out the key factors, constructs, or variables, and presumes relationships among them" (Miles and Huberman 1994), and it provides an understanding of a phenomenon through the interpretation of intentions (Levering 2002). The author accordingly developed both a narrative and a graphical representation of DDPSS, for showing the key dimensions that concur in the service provider and the relationships between them.

iii. *Multiple case studies.* Multiple case studies have been used to verify constructs, and to ensure that the framework was able to cover all DDPSS typologies that the companies are offering, by mean of observation, description, and measurements. Specifically, semi-structured interviews have been performed with seven heterogeneous industries, both considering the level of maturity into the service path, the products and the application domains and technological readiness. The heterogeneity between them has been defined as a requirement for the validation since it ensures the completeness and the generalisation of the framework, which aim to address each DDPSS typology in different contexts. During this step, the initial framework has been progressively adjusted based on case outcomes, changing the initial model.

iv. *Application:* In the end, when the framework has been defined, it has been finally used in an industrial case to map the actual service offering, to demonstrate its applicability and accuracy in describing DDPSS utilising the identified categories. Furthermore, the application has been used to show that the framework may also support companies in the identification of future service offering; indeed, it is possible to hypothesise different paths to enhance the actual offer.

3. The DDPSS Conceptual Framework

3.1. Overview of dimensions

Based on existing relevant literature, different characteristics of DDPSS have been identified that the author categorised into different dimensions that compose the first hierarchy of the framework. Specifically, literature analysis started analysing the papers into the corpus of the previous literature review falling into the CL1 "Digital Servitization transformation" (see chapter II) and other relevant works on the topic. The analysis of papers and the multiple case studies led to focus on four recurring characteristics that have been formalised into the following dimensions: ***(1) Data Source (2) Data Visibility, (3) Response mechanism and (4) Decision Ownership.***

Table 12 summarises the contribution of different works to the definition of the dimensions included in the final conceptual framework. The dimensions have also been characterised considering different options that the single dimension allows. Thus, in the following, for each dimension, the different characterisation has also been reported and explained.

The reported dimensions and categories, as well as the framework, are the ones that emerged at the end of the recursive cycle of the theory building approach.

Table 12 - Framework dimensions and relative references

	*DATA SOURCE**				*DATA VISIBILITY*			*RESPONSE MECHANISM*		*DECISION OWNERSHIP*			
	Product	*Operations*	*Enterprise*	*External*	*Customer*	*Customer & Produc-Service Provider*	*Customer Product-Service Provider & 3rd party*	*Automatic*	*Decision Support System*	*Product*	*Customer*	*Product-Service Provider*	*3rd Party*
(Demirkan 2015)	***X***	***X***	***X***		***X***	***X***	***X***						***X***
(Lerch and Gotsch 2015)	***X***	***X***							***X***				
(Opresnik and Taisch 2015)					***X***	***X***	***X***		***X***				
(Zancul Et Al., 2015)	***X***	***X***	***X***			***X***			***X***		***X***	***X***	
(Kamp Et Al., 2016)		***X***			***X***	***X***	***X***	***X***	***X***	***X***			
(Sambit Et Al., 2016)		***X***						***X***	***X***				
(Shin Et Al., 2016)		***X***					***X***	***X***					
(Shih, Lee, and Huarng 2016)		***X***			***X***	***X***		***X***	***X***				
(Coreynen, Matthyssens, and Van Bockhaven, 2017)	***X***	***X***	***X***								***X***	***X***	
(Rymaszewska, Helo, and Gunasekaran, 2017)		***X***			***X***	***X***	***X***	***X***					
(Grubic 2018)								***X***		***X***			
(Heinis, Loy, and Meboldt 2018)		***X***										***X***	

(Lindström et al. 2018)	X	X		X	X	X	X		X		X		X
(Mani and Chouk 2018)		X			X								
(Rabetino and Kohtamäki 2018)						X	X				X	X	X
(Rizk, Bergvall-Kåreborn, and Elragal, 2018)				X				X	X	X	X		X
(Zheng et al. 2018)	X					X		X					
(Basirati et al. 2019)	X	X						X	X	X			
(Frank et al., 2019)										X			
(Jovanovic et al. 2019)							X					X	
(Kohtamäki, Baines, and Gebauer 2019)							X	X	X	X	X	X	
(Lim et al. 2019)	X					X			X				
(Sklyar, Kowalkowski, Tronvoll, and Sörhammar, 2019)							X						
(Q. Zhang et al. 2019)	X						X	X	X	X			

* If marked as a single cell, it means that the paper does not refer to all of the categories but to the overall dimension

3.1.1. Data source

As already stated by Porter and Heppelmann, 2014, the capabilities of SCP are expanding industry boundaries. Manufacturers are more and more moving into a domain where, in addition to data coming from the machinery, other data may be gathered both on a machinery level but also at a process level, such as efficiency and productivity parameters, utilisation, quality of the production and so on (Sambit, Vinit, and Joakim, 2016; Rymaszewska et al., 2017). This not only means the competition shifts "from discrete products to product systems consisting of closely related products, to systems of systems that link an array of product systems together" (Porter and Heppelmann 2014) but also that the service may reach those scopes. The manufacturer has the possibility to continuously auditing customer's operations (Sambit et al., 2016; Coreynen, Matthyssens, and Van Bockhaven, 2017) and to expand value creation operating within the field of product use (Rymaszewska et al., 2017). ***"Data source"*** emerges as a crucial dimension to consider, which identifies available or potentially available data, to be integrated into the service offered by the manufacturing company.

Some data categorisation already exists in the literature, that tried to formalise and give order to all possible data sources. The one proposed by Hartmann et al., (2016) is specifically oriented to the service domain. Nevertheless, these classifications remain focused on data provenience and not directly linked to the possibility to exploit those data in the context of service. This research, instead, focuses on those data that reflect the possible service offerings and that may impact the design of new services. Accordingly, four different data-categories have been defined that influence the scope of the service that a service provider can offer: *(i) Product data, (ii) Operations data, (iii) Enterprise data* and *(iv) Contextual data.* Depending on the product specification, the meaning of the different categories may slightly vary. Indeed, what product means changes with respect to the manufacturing company, and it can span from component to machinery or a complete production line.

In the same way, all the other categories could change in their meaning. Nevertheless, besides different "product categories" exist, the levels apply to all product typologies. An explanation of all different categories is reported in Table 13, as well as different explicative examples to provide evidence of the general applicability regardless of the context.

Table 13 - Data source categories

	Category	**Description**	**Examples**		
			Tractors	*Trucks*	*Circuit breaker*
Data source	**“Product”**	Data are related to the product identity, such as serial number, location, provenience, technical features, age In this category data related to the product heat status are also included	Machine location, ID Health conditions	Vehicle position Health conditions of parts Truck movements	CB locations CB components status
	“Operations”	Data are related to the machinery operations, they may regard efficiency and productivity, or quality. It also considers the possibility to gather data from the system in which the product is primarily included.	Hour usage, average moisture, seeding variety and rates	Fuel consumption, Speed, Drivers Behaviour	Energy consumption, power factors, loads in the electrical system
	“Enterprise”	Data gathered thanks to the integration of additional sensors or sources within the customer ecosystem, which is the environment in which the product works, such as production scheduling, orders status, etc.	Cultivation, quality, extension of the yield	Position of destinations, distances, dates	Energy contracts, production and maintenance plan
	“Contextual”	Contextual data can be external or customer-related, i.e. are retrieved from a different source of knowledge, open and always available, which can be related to the external environment. It can also be concerned with regulations, geographical dependency, customer location and history and so on.	Soil and air temperature, solar radiation levels, precipitation	Traffic conditions, Environment Reports	Humidity, weather, Energy costs

3.1.2. Data visibility

Data sharing has been recognised as a critical point in the provision of DDPSS. Indeed the exchange of data has always represented a possibility for a high level of customisation, configuration and implementation of solutions (Sambit, Vinit, and Joakim 2016). Some authors also explain the need to convince customers to effectively share their data through the clarification and assessment of value creation (Ostrom, Parasuraman, Bowen, Patrício, and Voss, 2015; Rymaszewska et al., 2017). ***"Data visibility"*** dimension represents in this work the level of visibility and access to data from different actors.

Table 14 - Data visibility categories

	Category	Description
Data visibility	**Customer**	Data are available only to the customer. Often, the customer uses just a little part of those data, and it is not able to transform them into useful information. The customer may choose to send, remotely show data to the service provider in a specific case.
	Customer and Service provider	Data are available to the customer, and the service provider can access customers data continuously. The product owner can leverage data from many of his products at different customer locations and increase his knowledge and expertise over time based on different experiences.
	Customer, service provider and 3rd party	Data are available to the customer, service provider and other parties. Those other parties can offer new services, considering the possibility that they own different data, both in terms of quantity and source. They theoretically have the knowledge and expertise based on a more significant sample or different business. Moreover, they can own different data in terms of category and thus offer a completely new service.

Three different categories of data visualisation have been defined. They include the possibilities in which (i) only the customer can access his data, (ii) the customer shares the data with the service provider or (iii) data are shared with other actors that will be called generally "third parties". Those actors can be part of the service provider traditional network or can be outside the 'firm's boundaries. Third parties may have the knowledge, expertise or resources that the traditional provider lack. Moreover, they can own different data, that integrated with the ones shared will create possibilities for new service. The participation of a 3rd party in the network may offer opportunities regarding access and sharing of resources, including knowledge and capabilities (Loukis et al. 2017). This dimension directly influences service typology and data analytics opportunities since different actors may be enabled to exploit data and deliver services (Sklyar et al., 2019). Table 14 better explain the differences between the three categories.

3.1.3. Response mechanisms

Data availability has always played a central role in facilitating analysis of a situation and make the best decisions and data science and analytics, for their nature, have the goal of improving decision making. Having access to data, data elaboration and information facilitate the analysis of a situation and lead to best decisions (Provost and Fawcett 2013). ***"Response mechanism*"** dimension has been proposed to describe the output of the data analytic phase.

Two different possibilities may emerge for what concern the "*response mechanism"*, which are (i) an automatic response from the product to a specific input, which requires a stream of data that are not shown to an operator, or (ii) an analysis of data that is provided to a human user in order to support his decision-making process. Considering the possibility of a product to reasoning and act, different levels of intelligence have been found in the literature (Kiritsis 2011), and they all refer to the functionality that the product embed and related literature deal with smart product topic. Nevertheless, data gathering allows developing service based on data analytics aimed at interacting with a human in order to inform and support him/her in the decision-making process (Provost and Fawcett 2013). New features that companies that offer integrated solutions are either targeted to support customer decision making, with monitoring, control, optimization and to provide crewless autonomy as a service (Kohtamäki, Baines, and Gebauer 2019).

Table 15 reports a more in-depth explanation of the two categories.

Table 15 - Response mechanism categories

	Category	Description
Response mechanism	**Autonomous**	The product has embedded intelligence that is able to react to simple events and more sophisticated situation with simple logic. For example, a simple intelligent mechanism can be seen in the thermostat applications which allow the refrigerator to modify temperature according to the external one. Sophisticated changing environments are for examples ETS systems of cars. The car is able to adapt the trajectory in accordance with road conditions.
	Data supports decision making	The decisions to be taken on data are complex and subjective to reasoning and expert interpretation. Data can be transferred as raw data or elaborated at the product level and then transmitted to a Human Machine Interface, which can be a PC, a web platform or other devices. Data are used to support the decision-making process at different levels, from the operational to the strategical one, rather than enable automatic response. For example, a well-known ice-cream machinery producer offers analytics services able to support both operators in the efficient use of the machinery and the production planning decisions providing machinery parameters, ice-cream consumption trends and weather forecast.

3.1.4. Decision ownership

The level of interaction and responsibility of different actors along the decision-making process may change and can reach the final step where a decision is made, so that an activity is outsourced and delivered as a service from the DDPSS provider. Outsourcing activities or whole processes to the service provider have always represented one of the service businesses, and digital services can contribute to it. (Urmetzer, Neely, and Martinez, 2017; Frank et al., 2019). In this work, the **"*decision ownership*"** dimension has been included to identify who perform the decision. Particularly, this dimension defines if service providers are adopting a passive or proactive strategy towards service provisions and define who is responsible for the decisions and assumes the risk of it.

Four different categories have been defined considering the "*decision ownership*" dimension, which represents the possible actors who can act based on the information provided by the system and indicated who owns the operational responsibility on the decision (Urmetzer, Neely, and Martinez 2017). The decision may refer both to the fact that the product or the system of products autonomously reconfigure to reach specific scope and the fact that the service provider or third parties act on behalf of the customer based on data gathered. Indeed, the product itself has also been included in the categories since when the response mechanisms are autonomous, the product is responsible for the decision. Table 16 better explains the categories that have been identified.

Table 16 - Decision ownership categories

	Category	Description
Decision ownership	**Product**	When embedded logics are performed, the product itself acts to perform a decision that has been already settled in its memory. When there are not embedded logics, data analytics is just a part of the decision process and different actors can perform decisions.
	Customer	The customer decides the action to perform, with respect to the data or information provided by the PSS provider.
	Service provider	The service provider decides what to do on the basis or real-time data stream that enable him to take actions when is needed.
	3rd party	Other service providers oversee the decision, again considering the data-stream on which they should have the visibility.

4. The DDPSS Conceptual framework

With the prementioned aim of defining key DDPSS characteristics, after the definition of the crucial dimensions into the DDPSS, that have been presented in the previous section, the relationship between them have been investigated, leading to the definition of the final framework and the different DDPSS typologies.

Figure 25 graphically represents the final framework and how the different dimensions interact. As it is possible to notice, "*Data Source*" is represented on the vertical axis, creating three layers that are representative of different purposes of the service. Indeed, they represent different service scopes, that are encompassed in the framework according to three of the dimension categories: product data, operations data, and enterprise data. The three layers have been renamed based on the scope that those data provide as follows:

- *"functional services"*, which are based on product data, refers to services devoted to the product itself and its uptime. Services like maintenance, troubleshooting or spare parts management are included in this layer;
- *"operational services"*, which are based on operations data, refers to services related to product functionalities, utilization, performance and customer operations with the product(s). For example, this category may include product efficiency analysis and enhancement, optimization of the different SCP together etc.;
- *"business services"*, which are based on enterprise data, includes all the services concerning several areas of the customer business, considering, for example, the whole customer processes, the allocation of resources, the financial sphere, strategical decisions for supply etc.

As in the case of "Data sources" categories, those layers may include different services concerning the product considered. It has to be noticed that "Contextual data" has not been included as a different layer, since it does not create an additional service scope and may always be available in addition to other data.

"Data Visibility", "Response type" and "*Decision Ownership"*, instead, lie on the longitudinal axis. The different interaction of those dimensions creates distinct services typologies and values for the customer that are identical for each of the three layers. For each service scope, those three dimensions interact together. As it is possible to notice, the "*response mechanism*" dimension limits the "*decision ownership"*, in the case of an autonomous reaction, since the only category allowed in the decision ownership is the "product". All the other combinations in the framework are possible.
Table 17 reported the description of the service typology according to the different configurations that are concerned with the conceptual framework.

Specifically, six service typologies have been defined, considering their differences in the delivery process and in the roles that participating actors covers. Those typologies are then replicated in the three layers where they assume different service scopes.

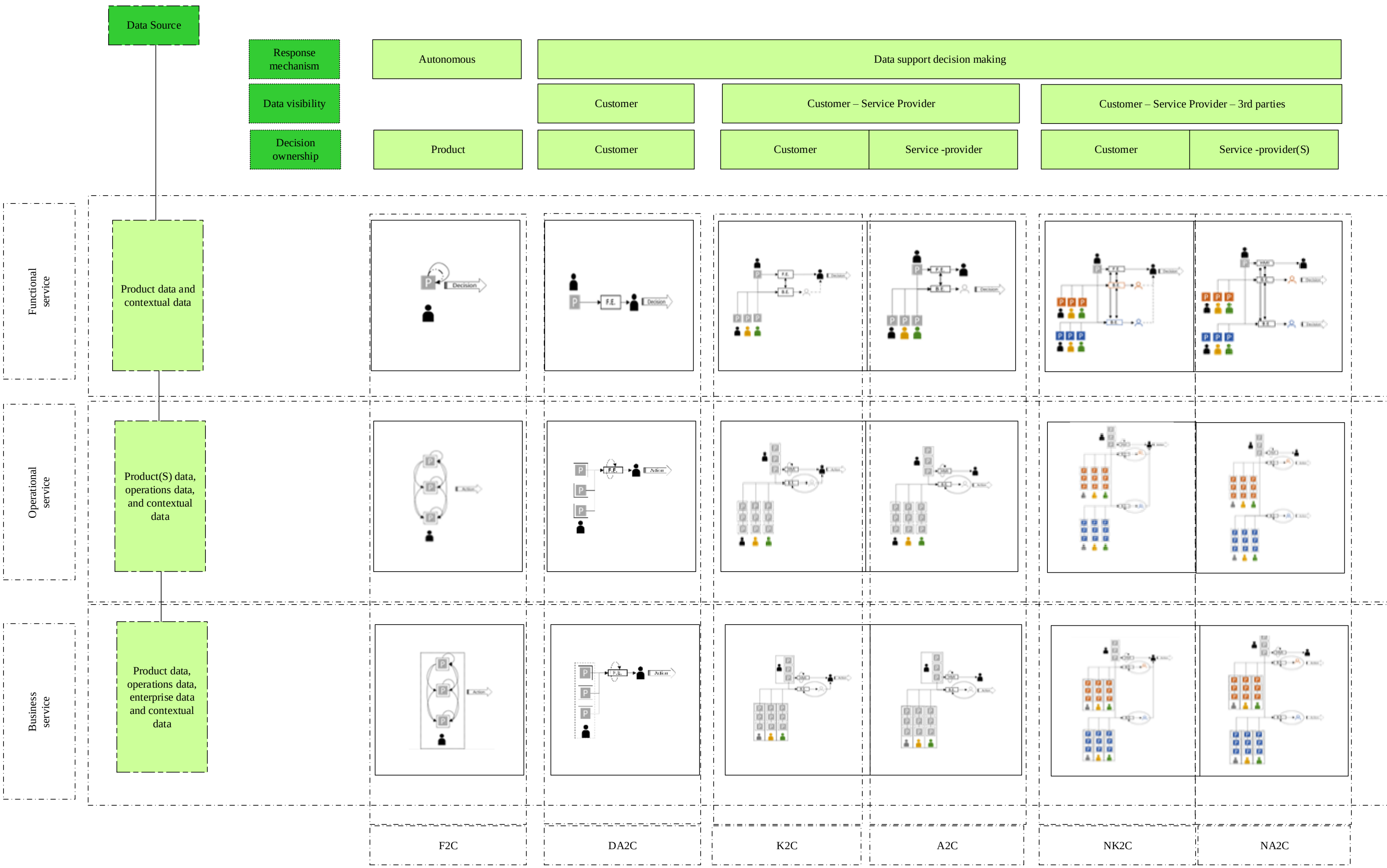
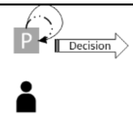
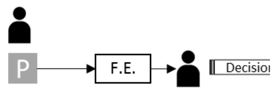
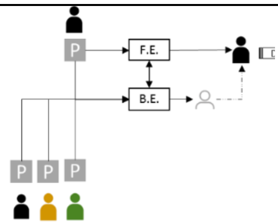
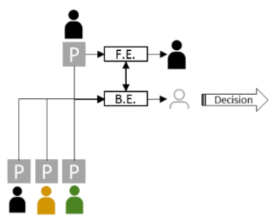
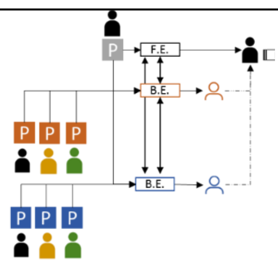
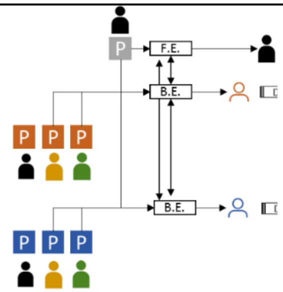


Figure 25 – DDPSS conceptual framework

Table 17 - Service Typologies

Service Typology	Graphical representation	Description
F2C (Functionality to Customer)		Product is capable of understanding specific data and can react at some changes automatically with simple mechanisms thanks to embedded logics (actuators) and thus, performing new functionalities.
DA2C (Data and Analytics to Customer)		The product can collect and store data. The customer can see those data on personal support or on a front-end support, provided by the PSP, which directly communicates with the product. Data analytics can be perfomed by algorithms delivered passively by the manufacturer on the front-end platform or by the end-user itself, who then takes action.
K2C (Knowledge to Customer)		The product can collect and store data. Those data can be seen by the customer on personal support or a front-end support, provided by the PSP, which directly communicates with the product. Data analytics can be performed by algorithms delivered by the manufacturer on the front-end platform or by the end-user itself. Moreover, analysis can also be performed by algorithms or by experts at the PSP side, who can provide customised and proactive insight and/or suggestions to the final customer, who then takes action.
A2C (Action to Customer)		The product can collect and store data. Those data can be seen by the customer on personal support or a front-end support, provided by the PSP, which directly communicates with the product. Data analytics can be performed by algorithms delivered by the manufacturer on the front-end platform or by the end-user itself. Moreover, analysis can also be performed by algorithms or by experts at the PSP side, who directly takes action.
NK2C (Network Knowledge to Customer)		The product can collect and store data. Those data can be seen by the customer on personal support or a front-end support, provided by the PSP, which directly communicates with the product. Data analytics can be performed by algorithms delivered by the manufacturer on the front-end platform or by the end-user itself. Moreover, analysis can also be performed by algorithms or by experts at the PSP side, and in the same manner by 3rd party SP. SP(s) provide insight and/or suggestions to the final customer, who takes action.

NA2C (Network Action to Customer)		The product can collect and store data. Those data can be seen by the customer on personal support or a front-end support, which directly communicates with the product, is provided by the PSP. Data analytics can be performed by algorithms delivered by the manufacturer on the front-end platform or by the end-user itself. Moreover, analysis can also be performed by algorithms or by experts at the PSP side, and in the same manner by 3rd party SP. SP (s) directly act based on their analytics.

Legend

	Customer. It identifies product location in the customer environment, (Different colours identify different customer)		Product Service Provider (PSP) Service Provider (PS) (Different colours identify different service providers)		Product, system in which the product works, and customer's business
F.E.	Front end platform	B.E.	Back end platform		Product and system in which the product works
	Elaborated data-flow		It can be both raw data-flow or elaborated data flow		Product (Different colours identify different products)
Decision	Perform Decision				

5. Multiple case studies

Multiple case studies have been performed to validate, refine and enrich the initial conceptual framework. Within the case studies, the focus was to determine their service offering in accordance with the predefined characteristics and understand if the model was able to map each of them. The conceptual framework thereby assured the right dimensions were addressed. The goal was twofold: determining if all the relevant strategic dimensions were considered and if the framework was applicable and complete.

5.1. Case selection and methodology

As already mentioned, the companies participating in the multiple case studies, have been chosen in the Business-to-Business (B2B) heterogeneous contexts, considering the need to map as many as possible different services and features. Indeed, the heterogeneity between them has been defined as a requirement for the validation since it ensures the completeness and the generalisation of the framework, which aim to address each DDPSS typology in different contexts. Their differences may be noticed in the level of maturity into the service path, the products and the application domains, the technological readiness and the position into the network. Table 18 reports a brief description of all the companies.

Semi-structured interviews have been performed with them, and to enhance the reliability and validity of the data collection and elaboration activities, a specific research protocol has been defined (Voss, Tsikriktsis, and Frohlich 2002). The protocol is reported in Appendix B and was based on the dimensions that emerged from the literature, that represented aspects of being investigated, and it has been used as a guideline during the semi-structured interviews. For each company, the validation started with a preliminary interview to understand the digital servitisation path of them and to present the main objective of the project, illustrating the framework and define the boundaries of the analysis. Then, following the guidelines provided in the research protocol, detailed interviews have been performed with service managers and/or the responsible for the digitalisation process. Each interview lasted around two hours. During this step, the initial framework has been progressively adjusted based on case outcomes, changing the initial model and resulting in the four dimensions that have been described. The main evidence was then shared with each company and discussed, and a final validation of cross-cases results has been carried out with an inter-company workshop.

The last case, instead, has been analysed considering the possibility to use the framework as a supportive tool in the definition of new service offering. Indeed, it is used to analyse the current position and to propose new trajectories for the companies' service offering. The application shows how all the digital and data-driven offer of the company can be represented utilising the framework, and it also can support the company to start thinking at different offers to expand their portfolio. The case has been firstly developed by the researcher, considering her internal position in the company and the know-how achieved during the years, and has been then presented and discussed to the head of the company's team responsible for the development of new services based on data collection. The discussion let to the final TO-BE state presented in section 6.

Table 18 - Case company description

	Description
Case 1	Case 1 is the biggest Italian dealer of one of the world's largest equipment manufacturer of construction machinery and engines. They offer integrated sales solutions, rental and assistance in extractive industries, major works, infrastructures, construction, power generation, oil & gas and naval mechanics. The group counts for more than 50 bl USD revenue and more than 100,000 employees.
Case 2	Case B is part of a Swedish multinational company operating in the appliance market with more than 45,000 employees and more than 100,00 bl USD of revenue. The interviewed company works in B2B contexts, producing appliances for professional use
Case 3	Case 3 is an Italian company that offers industrial galvanising plants, recognised as one of the biggest five companies in the world in the sector of hot-dip galvanising plant engineering by turnover, serving 40 countries around the world.

Case 4	Case 4 is a young Italian software provider offering a cloud-based platform to support the delivery and sale of intelligent services, based on the data processing that a connected product can collect. The company embraces the concept of generality, trying to make generic needs that seem specific, thus managing to configure the platform for different types of products
Case 5	Case 5 is a subsidiary of a Japanese multinational engineering, electrical equipment and electronics company with 80,000 group employees and annual consolidated revenues of around 38 bl USD. The subsidiary is an Italian company world leader in the design, manufacture and maintenance of organic Rankine cycle machines.
Case 6	Case 6 is an Italian company leader in the design, manufacture and installation of complete equipment for the retail sector. The company produces, sells, and installs refrigeration cabinets and systems, modular cold rooms and isothermal doors, and shelving and checking counters operating internationally.
Case 7	Case 7 is a multinational company leader in electrification products, robotics and motion, industrial automation and power grids, serving customers in utilities, industry and transport. The company counts for around 28 bl USD and 110,000 employees globally. The case study is based on a specific business line that produces low voltage circuit breakers.

5.2. Cross-case finding

The different cases enabled the author to modify the preliminary dimensions and derive the final framework that has been described in Section 3. The initial framework, and the interview protocol, reported in Appendix B, was based on the data lifecycle, as proposed by Han Hu et al. (2014), considering two adaptations for the service perspective. As reported in Figure 26 “generation” and “acquisition” phases collapsed in “collection” and a final step, i.e. “deployment”, has been introduced considering the need to deploy the service to the customer (Zambetti, Pinto, and Pezzotta 2019).

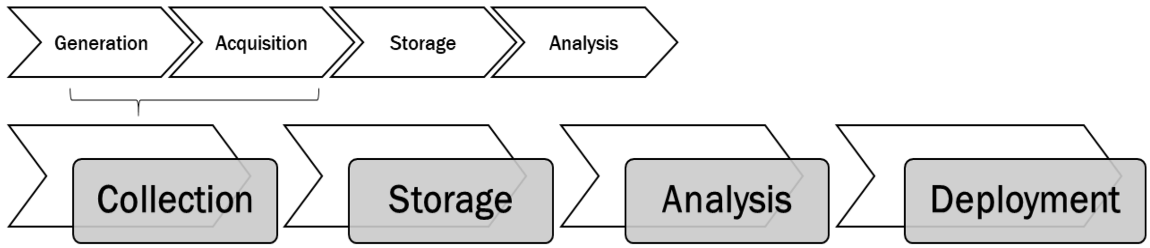


Figure 26 - Data lifecycle (Adapted from Han Hu, Yonggang Wen, Tat-Seng Chua, and Xuelong Li, 2014)

During the different interviews, the four basic building blocks have been then confirmed or disconfirms and, in the second case or when the block was not necessary, it has been either changed or excluded. In particular, only one block has not been modified during all the different rounds, that is the “collection”. For all companies, the different data collected represented the opportunity to develop different services considering their scope, that is why the final dimension of the framework has been named “Data source”.

As it is possible to notice in Table 19 and Table 20, different cases show different considerations both for data storage and the deployment, nevertheless, no specific difference has been found in the solution types they offer, while a strong emphasis has been found in the possibility for different actors to visualize data, leading to the definition of the “Data Visibility” dimension.

Table 19 - Contribution of different cases in the framework evolution (data storage)

Case	**Data storage**
CASE 1	Storage type has not defined as critical in the service provisions. In relation to the different clients, storage choices are different. While the possibility to offer specific service offering depends on the possibility to see data.
CASE 2	All data are stored in a cloud base environment, nevertheless, specific clients asked for a cloud partition to avoid the company access data.
CASE 3	Storage is locally based to the client, nevertheless, this does not limit the company to access customer data, who give them visibility.
CASE 4	All data are stored in a cloud base environment, which ensures scalability. The solution is sold as it is without choice for the customers.
CASE 5	Data is stored at the customer location and the company has access to data on requests.

Table 20 - Contribution of different cases in the framework evolution (data-driven service deployment)

Case	Data-driven service deployment
CASE 1	The adopted platform is not open but support the integration of 3rd parties with API and let them visualization of specific data
CASE 2	The company is prone to implement API on its platform to allow other actor having access to a specific set of data.
CASE 3	The platform is totally closed and proprietary, data are shared only between customers and service provider.
CASE 4	The platform allows third parties to interact and deploy service thought API, given them access to part of data or only providing a triggered which activate another service
CASE 6	The platform is not open, while data are shared with different stakeholders at different levels
CASE 7	The company is working on API to allow data flow between several applications

Also considering data analytics, the different approaches of companies has been investigated, nevertheless, as it is possible to notice in Table 21, there is no specific impact on the services offered, besides the consideration of who act based on those analysis and who owns the responsibility, thus assuming the risk for the decision. This lead to change the data analytic block, which was decomposed in two dimensions: “response mechanism” and “decision ownership”.

Table 21 - Contribution of different cases in the framework evolution (data analysis)

Case	Data analysis
CASE 1	Data analysis can vary from logics that are embedded to the product itself and analytics deployed to the customers that can be of different types, from descriptive to prescriptive, but usually, the customers do not own the knowledge to interpret information and require action from the company.
CASE 2	Analytics provided to the customers are most of the times descriptive and historical, the information provided is quite simple, and often the customer can interpret and use them for informed decisions.

Case	Data analysis
CASE 3	Analyses are very different for different applications and go form chemical analysis that can control the different solutions in tanks automatically, to other statistics deployed to the customers or degradation analysis of the plant that are usually interpreted by skilled employees.
CASE 5	Basic analytics are provided to the customer mainly for monitoring and reporting purposes, data are then interpreted by service engineers who own the know-how to derive actionable insight.
CASE 6	Customers access to descriptive analytics and historical resorts, while service partner performs analysis on product data or interpret malfunctioning based on descriptive analysis.

After changes have been made, confirmation on correctness and completeness of the model have been carried out and all the different categories have been defined, as reported in the remaining of the presented chapter. Even though different cases reflect different approaches through data-driven Servitization and strategical plans; it has been possible to define from the group analysis that the dimensions presented are the ones suited and enough to represent all different offerings, indeed it was possible to cover with them all the DDPSS from the different companies.

Considering the “data source” dimension, the collection of data at different layers, enables the development of services which aim is not only concerned with machinery itself but with an extended scope, as demonstrated by different case studies. For example, CASE1 collects all the data related to the health of the machine, which allows providing maintenance and diagnostic services. They are also able to collect and process data useful to understand the use of the machine, to give indications of productivity, efficiency, operators performances and to suggest to the customer how better to organise their work or the utilisation of machinery. Nevertheless, data collection is not limited here; indeed, the company gives the customers the possibility to integrate, through APIs, customer management data and matching all information together, they can support them managing their work and order plans. Information is received from the machinery, that helps the operator in the working operations. This is also possible thanks to the collection of additional data that comes from

Considering “Data visibility”, industrial realities particularly contributed to the definition of the three categories. Indeed, CASE5 stated that technically 100% of their systems are online and, based on the customer request, technicians can remotely access the plants, visualise and modify machinery parameters, mainly for diagnostics and troubleshooting purposes. Moreover, they also implemented all the infrastructure system to continuously gather data from the machinery and enable the service engineers (who have the skills and know-how to interpret the data) to make regular data analysis and suggest to the customer intervention for maintenance and performance optimisation, proactively and predictively. Nevertheless, not all of the customers give the company the possibility to collect their data, losing the opportunity to receive customised suggestions and preventive interventions. CASE6 relies on external partners, coordinated by internal staff, to deliver responsive maintenance services and rely on external call centres for preliminary diagnostic services. The company decided to give them access to the part of the data of their competences, to save cost and time for interventions. While CASE 4 gives the possibility to share data through APIs to external selected actors, that allow the customer to benefit from multiple services from several companies.

For the “response mechanism”, CASE3 shows a high level of automatisms that the system is able to perform thanks to specific data: by setting input data like the weigh and the typology of the raw material, the system computes the time that each phase of the process should last in the different galvanised tanks. Moreover, it is also able to define which tank to use in accordance with the usage rate and to the status of the chemical solution inside the tanks, optimising the utilisation of all of them and the duration of the chemical solutions. Nevertheless, not all decision can be provided autonomously. For example, CASE7 developed a cloud-based platform that provides analytics tools that analyse both the product health status of different products and the energy consumption of the customer. Specifically, a standard algorithm computes and shows the comparison between the usual “lifecycle” of the product, with the one that is monitored while other dashboards compute the overall and loads consumption in different timeframes as well as the energy expenditure. Those services include real-time alarms based on thresholds and analogic input and descriptive analysis to the customer who should interpret information and autonomously decide what to do.

Finally, the “decision ownership”, clearly represented the different attitudes of companies towards service provision: CASE1 proactively performs maintenance services in a preventive way; CASE5 declared that their customer does not own the know-how to interpret data, considering above all the efficiency losses, nevertheless, since not all customer share data with them, only in some cases intervention are performed proactively. CASE7 provides an expected date for the next maintenance needed, computed by a dedicated algorithm, but let the customer the responsibility to call for an intervention. The decision may also refer to the products, e.g. CASE7 is able to make product coordinate with each other and adapt to use power supply resources under determined circumstances efficiently. Considering the network, CASE4 structured the platform to gather consumables and spare parts information, that can be sent through specific trigger directly to the right suppliers that may refurnish the customer or the service provider.

Overall, looking at the service typologies offered by the different companies, it is also possible to notice that most of them are still oriented to the product, offering more functional services than operational or business. However, they are interested in moving to other domains. It is also to highlight that the less explored categories are the ones related to the possibility to leverage the expertise and resources of third parties, which imply opening and reshaping their ecosystem, showing again the need to investigate ecosystem perspectives, as already emerged in chapter II.

Hereafter each of the cases participating in the multiple case studies is presented and each dimension of the final framework is explained. After that, some of the services that are offered by the company are mapped into the final framework, to show how it is possible to position them with respect to the analysed dimensions.

5.3. CASE 1

The company under analysis is the biggest Italian dealer of one of the world's largest equipment manufacturer of construction machinery and engines. They offer integrated sales solutions, rental and assistance in extractive industries, major works, infrastructures, construction, power generation, oil & gas and naval mechanics. The group counts for more than 50 bl USD revenue and 101,500 employees.

The digital journey of the company started from the manufacturer in 2016, combining the on-board technology of the machines with dashboards to show to the customers and final user data and information. At first, customers were completely unprepared to manage the data and found the platform oversized since all information was not organised into different interfaces targeted for each of the different users, as changed in posterior developments. Moreover, the average customer of the company has insufficient familiarity with data interpretation and uses the tool as a mean to control operators, not considering the possibility to use information as an input for optimisation and continuous improvement. The dealer has recognised the difficulties of customers in access data and their interpretation; therefore, he has created a proprietary platform for condition monitoring in which manufacturers data is integrated, and a lot of other customer information is also gathered. This enables the dealer to offer proactive services, to interpret customer data and provide them prescriptive approaches and supports on the decision to take. Going on with the journey, the manufacturer recognises to change the platform structure, to be simpler and developed with modules that may be visualised only on interest. Moreover, he also recognises the importance of the dealer's network, which owns the customer relationship and the knowledge to support customers that are not able to interpret information alone. Table 22 reports the description of the framework dimension according to the specific case. Those considerations, in addition to the description of the service offering, also enable to map the framework, as shown in Figure 27.

Table 22 - Analysis of dimensions CASE 1

	Data source
Product	The company is able to collect all the data of the machine protocol, including data related to the health of the machine itself, and allow to provide maintenance and diagnostic services. Parameters such as fluid consumption or exceeding critical thresholds are shown to the customer. Nevertheless, the customer is not always able to interpret all data.
Operations	The data collected is also processed to understand the use of the machine, to give indications of productivity and efficiency. For example, from engine usage data, it is possible to extract efficient and inefficient usage times and this information can suggest to the customer how to better organise work or use machinery. Weight sensors allow for processing KPIs on the amount of material transported over time, etc.
Enterprise	Customer management data can be integrated through APIs, and the platform can manage information about customers' work plans. For example, the scanned project can be loaded into the machine and in this way receives instructions for excavation.
Contextual	The machines are equipped with advanced sensors that can collect data related to the external environment (weight, depth, etc.). Besides, the dealer has integrated contextual data of the customer within the platform. This enables him to understand, for example, in case some data are not communicated into the platform if it is an error or it is caused by the customer working condition.
	Data visibility
Customer	The data is shown to the customers and the final user of the equipment. The customer usually approaches the tool as a control tool more than using data to analyses them and extract information. Nevertheless, the sensibility to data importance is growing year by year and the user dedicated interfaces have increased the platform utilisation from the customer.

Service provider	Customer data are continuously shared between the OEM and the dealers. The dealer has a structured control tower dedicated to the data analysis and they share necessary data to branch offices in the case there is the need to perform services.
3rd parties	Data are not shared with 3rd parties.
	Response type
Autonomous	Data gathered and product connectivity are used to enhance product functionalities and enable some autonomous operations. For example, the equipment is able to read the working plan and to stop digging when the right condition is met.
Data supports decision making	Data are also used to show specific information both to the end customer, to the dealers and the OEM to support their decision making.
	Decision Ownership
Product	In the cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	The client always has the power to interpret data and decide what to do. Nevertheless, he usually lacks the familiarity and the know-how to interpret those data.
Service provider	Usually, data are analysed from the dealer to understand critical parameters and to take care of needed maintenance directly. Considering other service typologies, related to efficient operations, the company is used to do consulting projects, but for now, it has not the power to conduct the entire operations of the customer.
3rd parties	Data are not shared with 3rd parties.

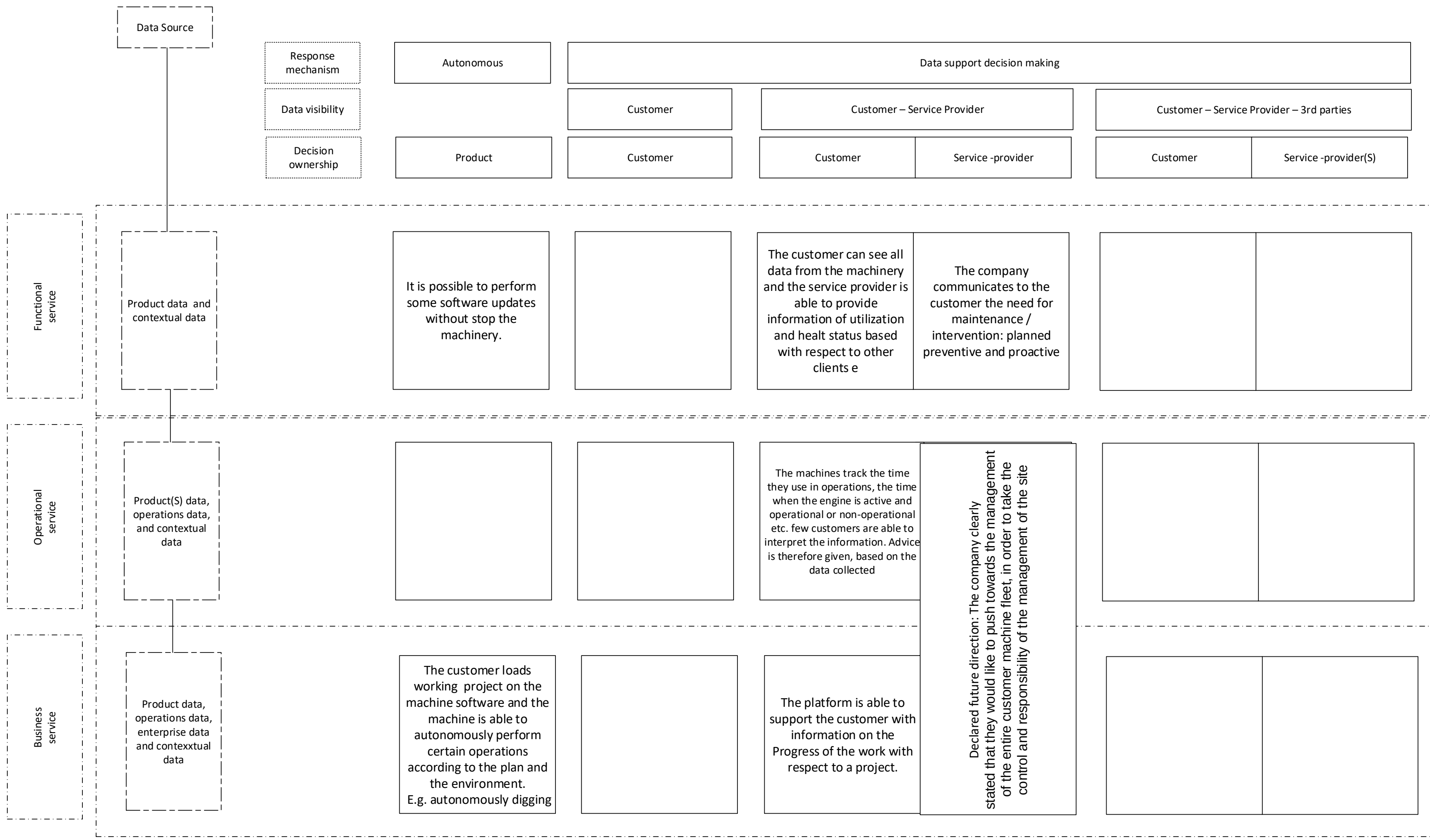


Figure 27 - Framework map CASE 1

5.4. CASE 2

The company under analysis is part of a Swedish multinational company operating in the appliance market with more than 45,000 employees and 127,34 bl USD of revenue. The interviewed company works in B2B contexts, producing appliances for professional use. Their digitisation process is in development as well as the implementation of DDPSS, despite for a specific product line data were collected at a local level from a long time, and some successful case has been already developed.

Their process is based on the following three strategic points:

- Connectivity: considering the need to develop both a back-end and front-end with dashboards for displaying information to internal and external users;
- Webshop: that is an online channel for the sale of products and services;
- Community: that is a virtual place that will represent the first point of contact for different pre and post-sales actors.

The company works on four different product lines, for which they are developing a dedicate platform. Nevertheless, the connectivity project has started only with two of them, which will be the focus of the case study, i.e. Food and Laundry. The aim is to enable the customers to manage all their operations, via the unique interface, using connected and synchronised products and services, in order to create business value. The company has also started specific pilot projects in order to understand the customer need and the definition of platform features and service offering. Table 23 reports the description of the framework dimension according to the specific case, both considering the actual offers and some experienced and desired features. In particular, the map will not be differentiated between different product line, even if the state of implementation is at a different level, the company aims to reach homogeneity. If some specific difference impacts the offer is then specified. Those considerations, in addition to the description of the service offering, also enable to map the framework, as shown in Figure 28.

Table 23 - Analysis of dimensions CASE 2

	Data source
Product	All data of the machine protocol is collected, including, for example, machine state, run time, alarms etc., This allows the customer to understand if the products need maintenance or repair. Despite this, maintenance services are not much relevant for most of the product typologies, as most of them are not critical applications and the customer usually has a redundant system.
Operations	Data is collected concerning the "operations" of the different types of products and are processed in the form of information and indicators of customer performance. For example, the amount of 'processed matter', cycle time, cycle type, machine efficiency, etc. are calculated.
Enterprise	The data that can be collected are all those managed by the machine, but it can also be related to variables other than those of the product itself. For example, for automatic laundries, it is possible to know the cost of the various cycles and thus, to the economic income of each point.
Contextual	Data regarding the geographical position and information of the customer are collected, while external data are not considered for now as a priority.
	Data visibility
Customer	There is a data visualisation platform for the customer, where data are organised into different interfaces and dashboard that shows relevant parameters, utilisation trends and KPIs.
Service provider	Data is not always visible to the company since customers have the opportunity to accept the sharing of the data or not. In particular, concerning the laundry segment, for which the digitisation process has already begun from several years, it is challenging to have permission to use the data because it is directly related to revenues. Many customers' data is, therefore, physically segregated on a cloud partition that was created specifically for them. Moreover, data is not yet systematically analysed internally.

3rd parties	The company is prone to share data and is working into the definition of who needs which data. They are also working for the identification of other companies to enable them to develop specific widgets and for data sales. As well as is considering creating APIs to other service providers, such as sending maintenance information.
Response mechanism	
Autonomous	Some of the appliances are able to perform some autonomous functionalities. For example, drying machinery is able to maintain a rotation when the cycle is finished and the load is not removed, in order to avoid fires, nevertheless, the application limits the scope of autonomous action and also, controls function from the platform.
Data supports decision making	Data are mainly shown to the customer in order to support their decisions. The definition of a back-end that will enable the analysis of data to perform internal decision is in the development phase.
Decision ownership	
Product	In cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	The client always has the power to interpret data and decide what to do. There are some successful cases in which the customer can interpret data, and both reduce costs and increase revenues thanks to data availability.
Service provider	The company has the know-how on the products, thus is able to recommend to the customer the better way to use them. Much time is the company that suggests to the customer how to utilise appliances better reducing wastes.
3rd parties	For now, data are not shared with 3rd parties, but the company is working on it, also considering the possibility for them to use those data to provide services to customers autonomously.

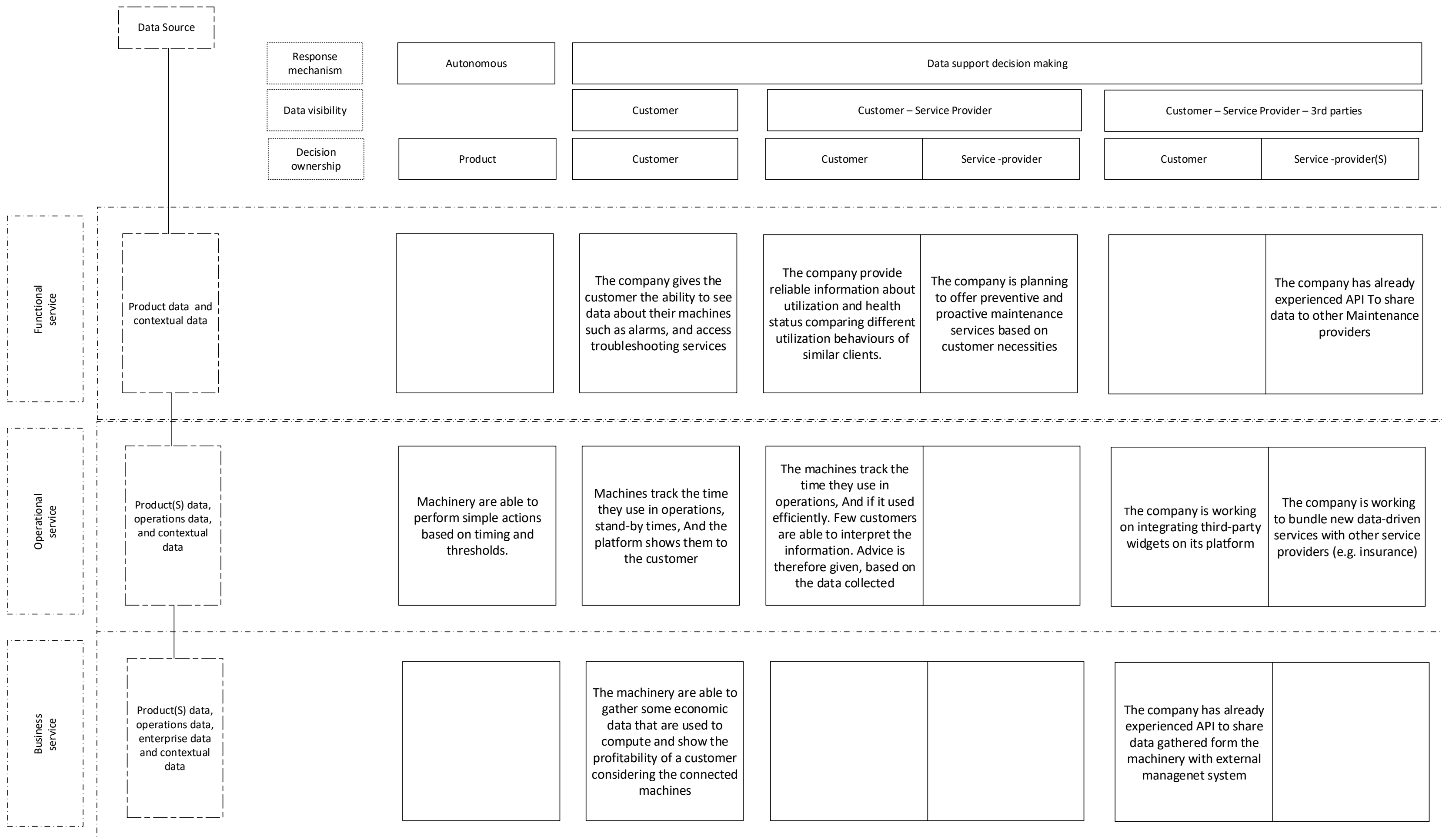


Figure 28 - Framework map CASE 2

5.5. CASE 3

Case3 is an Italian company that offers industrial galvanising plants, recognised as one of the biggest five companies in the world in the sector of hot-dip galvanising plant engineering by turnover, serving 40 countries around the world. Their solutions can include both standard configurations, including thermal (kiln-dryer) and chemical (degreasing-deaerator-fluxing) and articulated solutions including transport and lifting automatisms. As far as digital solutions are concerned, the company has developed several software packages able to support the customer in monitoring the entire plant, considering both the material handling and logistics part and the material processing phases. In particular, they developed a proprietary software they divided into three modules: Productivity, Chemical and MES. The first one collects data continuously from the automation system and returns elaborations about the productivity of the plant. The Chemical module manages the data of the chemical process of raw materials; the data are partly retrieved from the automation system and partly entered manually. The last module allows managing the entire information flow from the reception of the material to be processed to the delivery of the galvanised material. This module requires the interaction of an operator to enter some data that scan bar-codes developed for the software itself.

Table 24 reports the description of the framework dimension according to the specific case. Those considerations, in addition to the description of the service offering, also enable to map the framework, as shown in Figure 29.

Table 24 - Analysis of dimensions CASE 3

	Data source
Product	The company manufactures galvanising plants, designing and installing for the customer the entire production system. The heart of such a system is the galvanising part, for which a SCADA monitors all parameters.
Operations **Enterprise**	The same data is also shared with the company for connected installations. The data processed are therefore related to both the 'product", such as temperatures, flow rates, speed and to the system, which in this case is represented by the process itself. For example, the consumption of current, gas, and more specific indicators such as the consumption of methane/ton of produced material etc. are calculated.
Contextual	Also, the company has developed a software module that supports the customer throughout the process, especially about internal logistics. All material handling data within the plant is tracked. The software is interoperable with the customer's management system, in order to integrate information about galvanisation orders, the customer portfolio etc., avoiding duplication of systems.
	Data visibility
Customer	The customer has a complete vision of all data. They can access the SCADA system for controlling purpose, and they have access to the web-based software where critical parameters are recorded, and all the other tools are accessible.
Service provider	The data is not always visible to the company since customers themselves have the opportunity to accept the sharing of the data or not. Usually, access to the productivity module is granted to the manufacturer, while the ones that include financial information are not shared with him.
3rd parties	Data are not shared with 3rd parties.
	Response mechanism
Autonomous	The system is able to set specific parameters and the time that each phase should last in the different for the galvanised tanks considering input data like the weigh and the typology of the raw material. It is also able to define which tank to use

	in accordance with the usage rate and to the chemical solution inside the tanks, optimising the utilisation of all of them and the duration of the chemical solutions
Data supports decision making	Much information cannot be traduced into automatic responses from the system, since they require the final decision of a human operator. For example, the system is able to define how to adjust the solution composition of tanks by balancing the liquids in different tanks; nevertheless, the system requires the intervention of an operator to take action.
	Decision Ownership
Product	In cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	The customer has the possibility to perform analysis on data and is also supported with suggestions directly provided into the platform.
Service provider	For further analysis, the support of service provider, with his know-how, is necessary. Indeed, maintenance and process optimisation are also part of the company business. Nevertheless, there are few services for with the company takes action proactively, but usually, they support the customers in their decisions.
3rd parties	Data is not shared with 3rd parties.

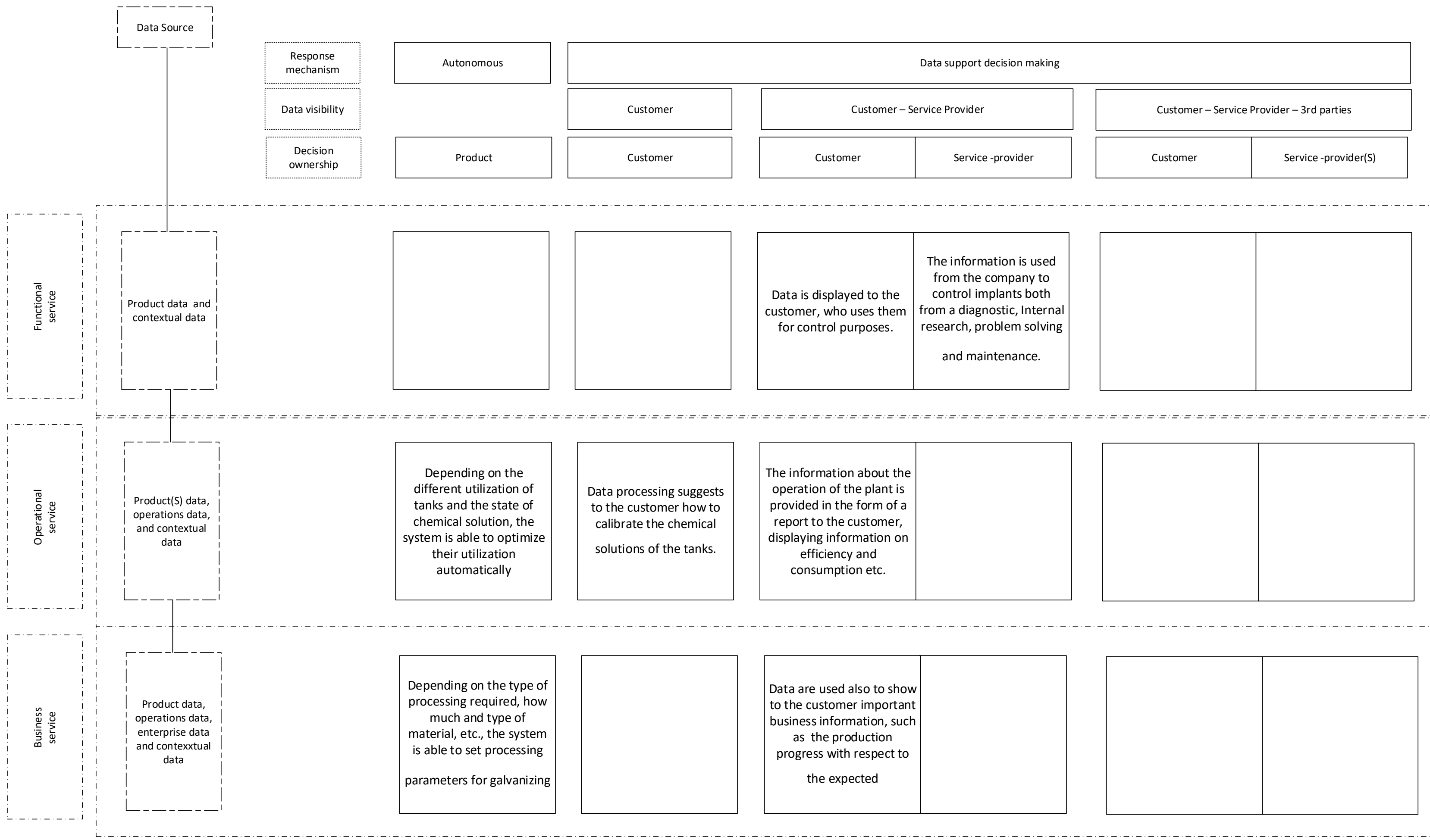


Figure 29 – Framework map CASE 3

5.6. CASE 4

Case4 is a young Italian software provider offering a cloud-based platform to support the delivery and sale of intelligent services, based on the data processing that a connected product can collect. The company embraces the concept of generality, trying to make generic needs that seem specific, thus managing to configure the platform for different types of products. The software architecture is modular, and each client decides which modules they want to use and offer to the end customer. Moreover, this enables the company to address companies' digital project at each stage, from the ones that start with connecting products, to the ones that want to implement advanced pay-per-use services. It usually works with professional industrial products used in business, but also with some B2B2C intermediates, for which interfaces are also integrated for the visualisation of some information for the final customer.

Table 25 reports the description of the framework dimension according to the specific case. Particularly, since the company represent the software provider and not the manufacturer either the service provider, the analysis has been done considering which possibilities the software supports and enable. Those considerations, in addition to the description of some application cases described by the company, also enable to map the framework, as shown in Figure 30.

Table 25 - Analysis of dimensions CASE 4

	Data source
Product	The platform collects data related to the products considering, for example, their uptime, health conditions, alarms, maintenance parameters, connection etc. The platform supports the delivery of maintenance services, predictive alarms, alert and so on.
Operations	The platform collects data related to the use of the product, such as stand-by times, processing times, parameterisation of the machinery for recipes, enabling customers to analyses efficiency, quality of the production and take action.
Enterprise	The platform may be directly connected to the company's CMR to collect, for example, data about the business organisation and also to the customers' management system like SAP.
Contextual	The platform also allows customers to include both environmental and contextual data of the end customer.
	Data visibility
Customer	There is a dedicated data visualisation platform for the customer, and different interfaces can be developed for different users. A mobile app is also available for them.
Service provider	The platform is structured with a dedicated back-end, where the data are structured for the visualisation from the manufacturer side. Ownership of data is of the manufactures from the beginning, and it is defined when the platform is proposed to the client.
3rd parties	The data is visible to different parts of the organisation, depending on the configurations that the OEM wants. Technicians are usually enabled to see specific data, which can be both internal and external. The data can be shared through APIs to other external selected actors. The platform also enables callbacks to send order or alert to other systems. It is in fact integrated with different software such as ServiceMax, Microsoft, Stripe and others.

	Response type
Autonomous	The platform enables callbacks to send order or alert to other systems utilising thresholds or specific other settings decided by the manufacturers. Moreover, there is the possibility to integrate optimisation and intelligent algorithm into the platform, that merged with the capacity to control products remotely, it is possible to perform automatic response directly embedded into the product.
Data supports decision making	Most of the functionalities are relate to the visualisation of data and information into the platform, to support the manufacturer, the customer and other service providers in their decision-making process.
	Decision ownership
Product	In cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	The final customer always has the possibility to visualise data and act accordingly. The decision ownership strongly depends on the software provider customer choices in performing the services. Usually, not all the end-user owns the know-how to interpret data and optimise the efficiency of the machine or the process.
Service provider	Lot of the times the software provider customer, which is the PSS provider, is able to interpret data and suggest to the customer how to organise operations better or set the machinery. For example, a manufacturer worked with some customers to identify ideal parameters for packaging, correlating product and operational data.
3rd parties	When defined from the platform rules, it is possible for a 3rd party to directly perform an action, such as perform maintenance upon some specific alarms.

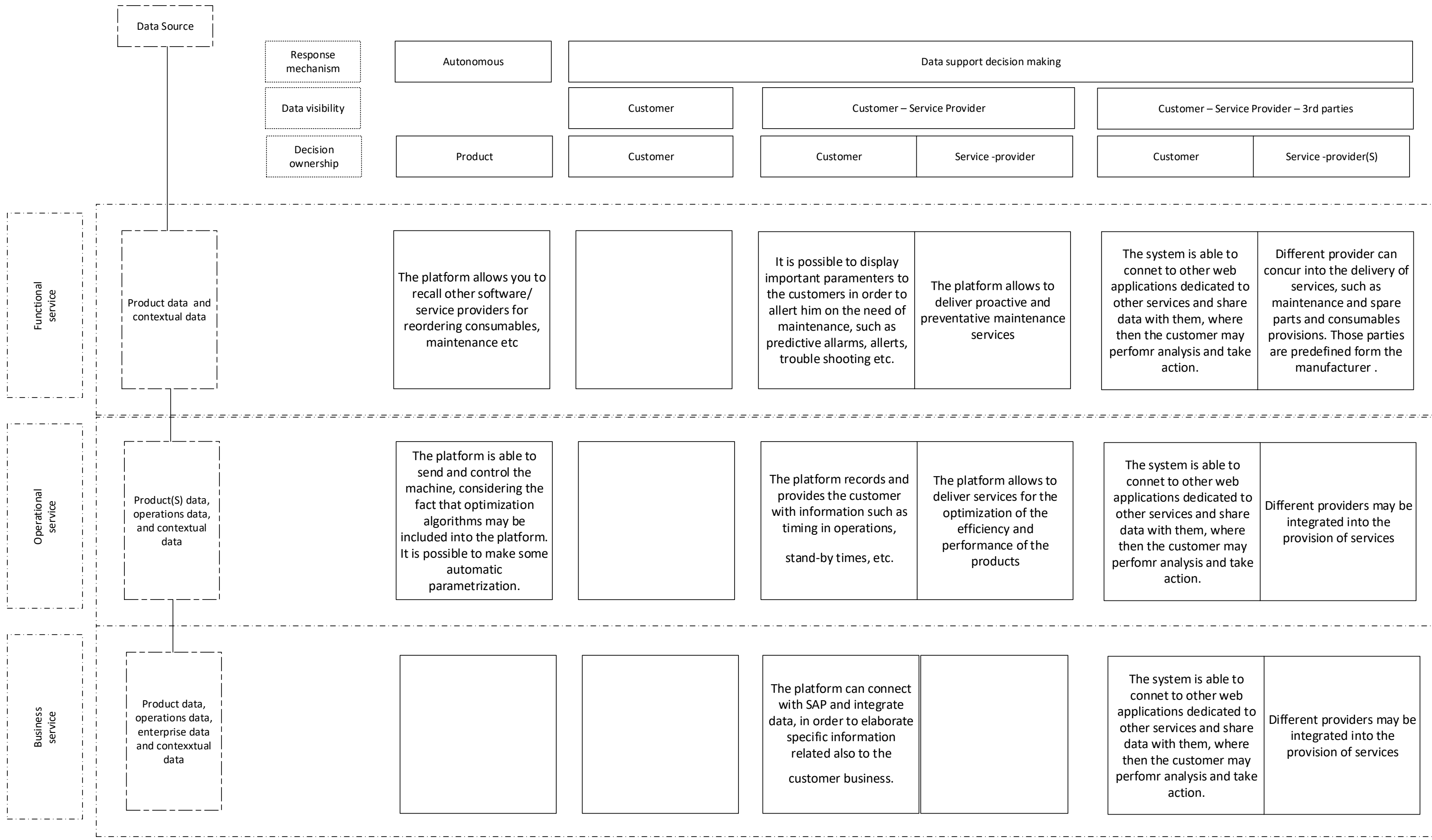


Figure 30 - Framework map CASE 4

5.7. CASE 5

The company is a subsidiary of a Japanese multinational engineering, electrical equipment and electronics company with 80,000 group employees and annual consolidated revenues of around 38 billion U.S. dollars. The subsidiary is an Italian company world leader in the design, manufacture and maintenance of organic Rankine cycle machines. These machines are able to generate electrical and thermal energy, using different sources, renewable such as biomass, geothermal, solar and non-renewable. These plants can also use waste energy from industrial processes. The company allows customers to view machine data through a SCADA system for several years and the local system also collects data in order to process trends and statistics describing the measured quantities. This system has also been designed to show data remotely to technicians and perform diagnostic analysis at the customer's request. Moreover, where customers allow, data is also recorded and shared in a database, which uses it to provide preventive and predictive maintenance services. Usually, customers rely on data and SCADA system in order to control the system, nevertheless, considering all technical problems, that may go from breakage to decreases in the efficiency of the cycle, the know-how of the company is in most of the cases necessary to understand data and translate it into action.

Table 26 reports the description of the framework dimension according to the specific case. Those considerations, in addition to the description of the service offering, also enable to map the framework, as shown in Figure 31.

Table 26 - Analysis of dimensions CASE 5

	Data source
Product	The platform collects product data. For example, electrical parameters, process temperatures, saturation temperatures etc. that enable the company to perform diagnostic and maintenance activities.
Operations	The platform collects data on the efficiency of the energy production cycle. The performance of the machine is measured and shown to the customer as well as the service provider, how is able to support the customers in optimising the cycle.
Enterprise	At the moment, some data are monitored but compared to the entire production system, they are partial. They are collecting data only if it is useful to define some KPIs/performances essential to place the plant in service. In theory, the database could be extended with data of customer interest but would involve an additional level of difficulty.
Contextual	External data needed to perform efficiency analysis, such as temperature, are collected. Moreover, the company owns also information for all of the customer, such as maintenance history, problematics etc.
	Data visibility
Customer	The customer has the opportunity to see data from the SCADA system, from the machinery PLC and data visualisation for the customer. The company is now defining how to implement a data visualisation platform and advanced services to share with the customer.
Service provider	All systems are online, considering the fact that at the request of the customer, technicians can remotely access the plant and view, but also modify the parameters of the machine, mainly for diagnostics and troubleshooting. The company also collects data, when the customer agrees, with lower frequencies sampling with respect to the ones in the SCADA system. This data is saved to log files that are then shared to the company server in order to be analysed proactively.
3rd parties	Data are not shared with 3rd parties. Some of them are not even interested in the business. For example, discussing the possibilities to share some data to spare part

	suppliers, in order to enable them to coordinate production upon requests, emerged they are not even interested into For others they did not start the evaluation, but they want to maintain the focus on core business.
	Response type
Autonomous	-
Data supports decision making	Data are gathered and analysed in order to enable the customer to control and monitor the system and decide how to behave mostly at the operational level. For more strategic decision, the customer has not the know-how to act. Information is in this case used by the provider in their decision making
	Decision Ownership
Product	-
Customer	The customers usually use the SCADA system for controlling purposes; however, considering the maintenance and optimisation, they do not usually own the competences to interpret them and take action.
Service provider	At the moment, the company does not have a structured back-end organisation dedicated to data analysis. However, the data is analysed regularly by service engineers, who have the skills and know-how to interpret the data and suggest to the customer intervention for maintenance and performance optimisation proactively and predictively.
3rd parties	Data is not shared with 3rd parties.

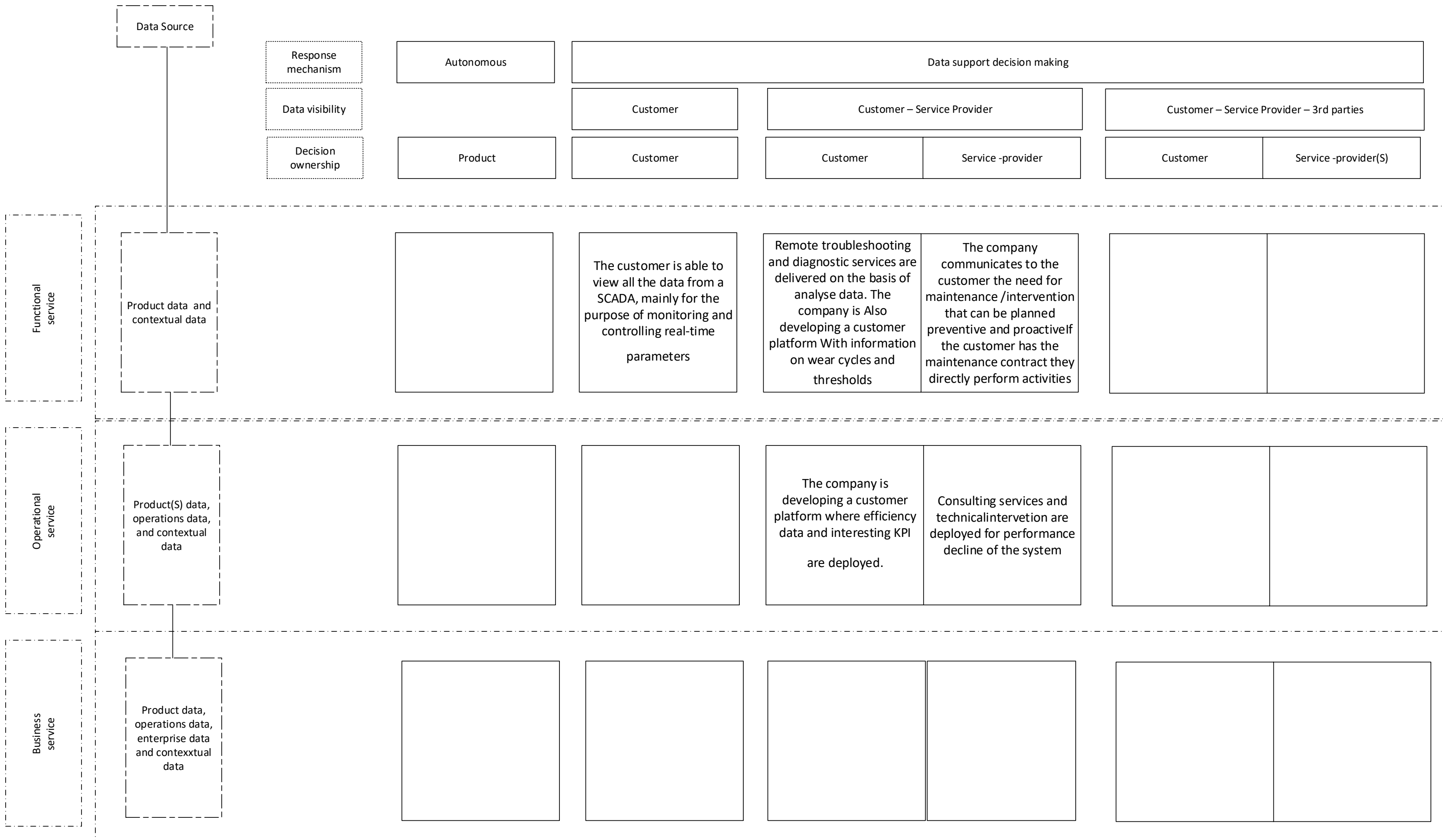


Figure 31 – Framework map CASE 5

5.8. CASE 6

Case6 is an Italian company leader in the design, manufacture and installation of complete equipment for the retail sector. The company produces, sells, and installs refrigeration cabinets and systems, modular cold rooms and isothermal doors, and shelving and checking counters operating internationally. Its leadership position in the commercial refrigeration sector stems from the exploitation of the synergies that are created between the various companies of the group and from a wealth of knowledge and ideas that circulate in a continuous flow of information through the production and distribution network of each continent. Today the company is a group that employs more than 2500 people worldwide.
Already in 2012, the company, among various innovative projects, started the study of new ergonomics for refrigerators with integrated energy-saving systems; and web-based control system for the performance of refrigerators was implemented. Now, the offer of digital aid on the product is successfully implemented for maintenance and energy management purposes. The company is still working on the continuous improvement of the offer and is experimenting with predictive and advanced analytics in order to offer new value to the customers.

Table 27 reports the description of the framework dimension according to the specific case. Those considerations, in addition to the description of the service offering, also enable to map the framework, as shown in Figure 32.

Table 27 - Analysis of dimensions CASE 6

	Data source
Product	The product is able to communicate different parameters that are relative, for example, to the temperature, fluids, lighting and so on, that are mainly used for control and maintenance purposes. All the company products are equipped with sensors, telemetry, controllers and electronics, nevertheless different products may differ for the data that can collect.
Operations	Different data form the products are used to compute efficiency and performances of the product. The company also decided to include data related to energy consumption, not considering only the product itself but retrieving data also from other utilities, like lighting and conditioning systems. This enables the company to offer a dedicate BMS and energy services.
Enterprise	The data that the company collects related to the management and economic aspects of the company are the ones that he personally collects for what concern maintenance, from the work that triggers the intervention to its reporting. Those data are also provided to the customers, giving them critical and updated information of all costs.
Contextual	The company is able to integrate a large amount of data needed to deliver the service. For example, weather data is used for energy management services; the temperature and humidity of the outdoor air are always monitored. Also, in order to define both the layout and all loads present in a retail store, the company needs to know the specificity of all customers.
	Data visibility
Customer	The data is of the customer, but there is not much sensitivity about them. Given that only a few indicators and a set of data are shown to the customers and, for each customer, the platform is configured according to customer needs and including only the modules and dashboards that are defined together.
Service provider	The company has a complete and real-time view of customer data, and depending on the customer contract, there are different monitoring activities in place, up to a continuous monitoring 24/7.

3rd parties	The company relies on external partners coordinated by internal staff in order to deliver responsive maintenance services, counting 180 service centres only in Italy. Dara is shared form the company to them giving access to the part of the data of his competences. Their call centres are also allowed to see part of the data. Data are not shared with 3rd parties that are not part of the company network. Exceptions are made only upon customer request.
	Response type
Autonomous	Some autonomous functionalities are provided for products, that goes from the simple reaction to temperature decline to self-regulation of the electrical system optimising energy consumption and evaluation of different energy sources. The system needs to be settled with specific logics that will guide the different decisions.
Data supports decision making	A large set of data is deployed to customers in order to support their decision-making process. Nevertheless, many times they are not confident in data interpretation and need the support of the manufacturer in order to understand and takes decisions on actions.
	Decision Ownership
Product	In cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	The customer has the possibility to interpret data and take action, nevertheless for maintenance and energy services they need the support of the manufacturer or other service providers. The data that they are more confident with are the ones of expenditure.
Service provider	The service provider analyses data and supports the customer in its decision, and depending on the type of contract that the customer has it can also perform maintenance autonomously and proactively.
3rd parties	Maintenance partners are allowed to take actions in accordance with the specific contract.

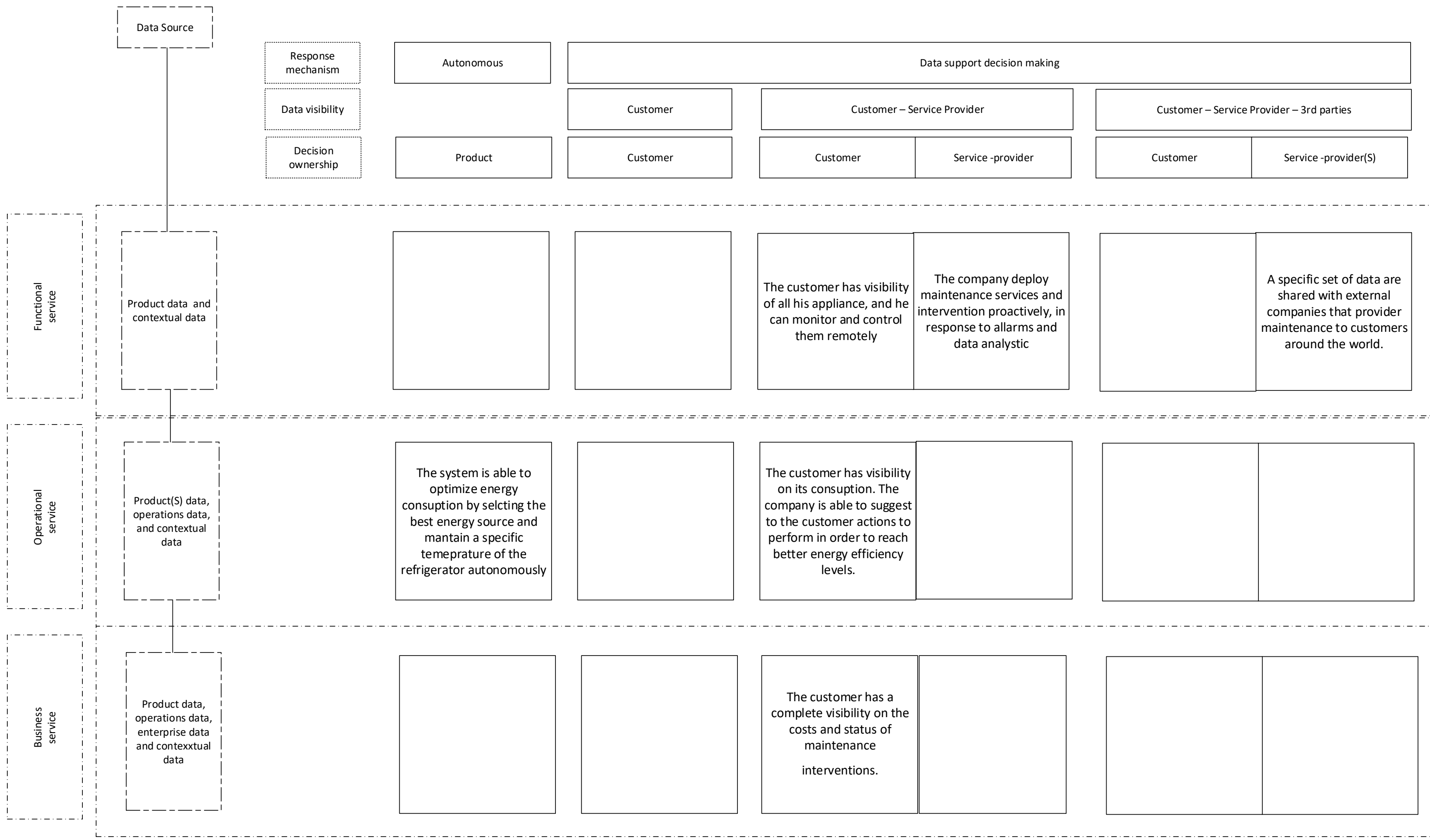


Figure 32 - Framework map CASE 6

6. Application case study

The last case, that is presented in this section, is the one used after the framework definition to test its applicability. It has been developed considering the descriptive potential of the framework for the current situation but also proposing the possible future state of the company under analysis (Case 7), to show how it is possible to use the framework to start thinking of possible future directions. Indeed, in this case study, the presented framework has been used first to examine the DDPSS that are now available (AS-IS state) and consequently to present some possible options to create new services (TO-BE state).

Particularly the TO-BE state has been developed guided by the different dimensions of the framework. Starting from the AS-IS state, it is possible to notice where the company is focused and identify the service typologies that are not covered yet. According to not covered dimensions or categories, it is thus possible to define possibilities and services that may be developed on them. Table 28 summarises the coverage of all dimensions into the AS-IS and the TO-BE State, while the following sections will extensively explain the two different states and examples of the DDPSS in each of them.

The TO-BE state has been firstly developed by the researcher and has been presented to the head of the company's team responsible for the development of new services based on data collection. The proposals have been discussed, and lead to the TO-BE state here presented. The framework has been considered interesting, the company was impressed by the identification of such possibilities, indeed, if on one side some of the offers were already programmed to be implemented or have been considered, some others were completely neglected. Another interesting insight that has been taken from the company is the guidance on the decision to outsource certain activities, indeed the map also helps in the definition of solutions that can be achieved through partnerships.

Overall, the company shows willingness to use the tool, even no other structured tools are now adopted at the preliminary stage of a choice on the portfolio, but decisions are related to the manager research and sense of the market, both considering customers and competitors.

During the discussion one of the main limitations of the framework has also been pointed out, i.e. that feasibility and managerial reflections should be included. Besides those considerations, it has to be noticed that at this stage, the development of the framework has not the intent to include feasibility and managerial consideration. Moreover, the primary scope of the framework is to define DDPSS characteristics and typologies and not be a prescriptive tool.

Case 7 is a multinational company leader in electrification products, robotics and motion, industrial automation and power grids, serving customers in utilities, industry and transport. The company has undertaken a digital transformation program that, starting from the introduction of connectivity and the creation of a cloud-based platform, is leading to the development of new services based on this continuous data flow. Even though the project embraces most of the products of the company, the case study is based on a specific product, i.e., low voltage circuit breaker (CB).

Table 28: Differences of dimensions between AS-IS and TO-BE state of CASE 7

	AS-IS	**TO-BE**
Data source		
Product	Covered	Covered
Operations	Covered	Covered
Enterprise	Partial	Covered
Contextual	Partial	Covered
Data visibility		
Customer	Covered	Covered
Service provider	Partial	Covered
3rd parties	Not Available	Covered
Response mechanism		
Autonomous	Covered	Covered

Data supports decision making	Covered	Covered
Decision ownership		
Product	Covered	Covered
Customer	Covered	Covered
Service provider	Not Available	Covered
3rd parties	Not Available	Covered

6.1. AS-IS State

As it is possible to see from Figure 33, which represent the AS-IS state, firsts DDPSSs have been focused on the product layer, on which the company is traditionally oriented. Data are automatically analysed to apply simple reactions that enable the product, for example, to coordinate with other products to use power supply resources (1) efficiently. Those capabilities are provided as embedded functionalities and are based on thresholds that are defined by each customer, in accordance with his need. Another step has been done by the company providing the possibility to connect the CB to a cloud-based platform and to retrieve data from the product. Data collected includes both "product data" and "operational data" which consider, in this case, the electrical one. Even though not all the time the access to data is given to the company, the platform provides analytics tools that analyse both the product health status (2) and the energy consumption (3). Other information can be computed for what concerns energy expenditure (4); indeed, if the customer sets the energy costs, it is possible to visualise the comparison of costs for different periods. Those services include real-time alarms based on thresholds and analogic input and descriptive analysis to the customer who should interpret information and autonomously decide what to do. Indeed, no decision are overseeing by the service provider or other actors.

In addition to that, some pilot project has been carried out in order to understand the possibilities that data gathered from the product, integrated with other business data, such as production, equipment efficiency and facility structures may create. It has been shown that all those data together enable the company to suggest to customers different strategies to enhance energy management and to compute specific performance indicators thanks to the support of experts in the energy field (5). Nevertheless, to be able to give prescriptive and personalised information to the customers, data need to be continuously visualised from the company moving offers on the second category of "Data Visualization" dimension. Indeed, in the AS-IS state, the company is not allowed from all the customer to access their data or a part of them, limiting the possibility for the company to offer DDPSS but also to internally analyses data to define and implement possible improvements.

Table 29 reports the description of the framework dimension according to the specific case in the AS-IS state.

Table 29 - Analysis of dimensions CASE 7- AS-IS

	Data source
Product	Data are related to product identity, such as serial number, location, provenience, technical features, age. In this category data related to the product heat status are also included, such as contact wear, the number of operations and so on.
Operation	In this case, the CB operation is to enable the correct energy flow at the customer location. Data of operation can be representative of all the energy system and comprehends all the energy flows as well as energy quality parameters. A CB is able to gather data on energy consumption and to convey all the energy flows into a single platform enable the service provider to collect data on the whole energy consumption of a factory
Enterprise	Enterprise data can be settled on the platform by the customer itself, who should, for example, indicate the energy cost of its contract or group the different energy consumption points that are monitored, in order to access some specific dashboards.
Contextual	Temperature data of the environment surrounding the CB are gathered through additional sensors, in order to enrich environmental analysis needed to compute the remaining useful life of the products

	Data visibility
Customer	Customers have a dedicated platform to visualise information and has the possibilities to export a lot of raw data to perform analysis. Maintenance data are not completely shown to the customers since they represent a competitive point for the company and need the know-how of them to be interpreted.
Service provider	The company is not allowed from all the customer to access their data or a part of them, limiting the possibility for the company to offer DDPSS but also to internally analyses data to define and implement possible improvements
3rd parties	The company does not give the possibility to other companies to use data in order to offer additional services. Some sporadic cooperation has been done with other entities, but not yet considering the possibility to give them freedom on the services
	Response mechanism
Autonomous	Data collection enable the functioning of specific software that is embedded with the CB that can realise autonomous logics to manage power peaks. Embedded logics are deployed thanks to data analytics and after an initial setting, the product is able to respond autonomously to some stimuli.
Data supports decision making	Even not all the time the access to data is given to the company, the platform provides analytics tools that analyse both the product health status (3) and the energy consumption (4). Those services include real-time alarms based on thresholds and analogic input and descriptive analysis to the customer who should interpret information and autonomously decide what to do. Indeed, no decision are overseeing by the service provider or other actors.
	Decision ownership
Product	In cases where some autonomous functionalities are performed, the product is considered as the decision-maker.
Customer	Since the company is not yet structured to analyse customer data, the customer needs to make decisions based on descriptive and few prescriptive analytics.

Service provider	For now, the company is not providing proactive services and suggestion to the customer based on data analytics. The company has not a structured back-end and organisation dedicate do data analytics and monitoring.
3rd parties	For now, 3rd parities cannot access data. Where some 3rd party application has been noticed as a possible new platform feature, it has been acquired by the company.

6.2. TO-BE State

In the TO-BE state, as it is represented in Figure 34, the company is supposed to gather data from many of its products at different customer locations. This will enable the company to analyse how devices are used and how they operate in different environments and to use that information both for new offerings and for the internal organisation. Working on product functionalities, the company may enable the CBs to automatically set their parametrization according to customer operations (6). Additionally, they may analyse different alarms for different CB and suggest changes in the electrical plant or discover critical loads that cause problems (7). Maintenance operators may directly contact the customer to propose maintenance activities (8), without the need that the customer monitors or understand specific machinery parameters. Moreover, in the AS-IS state, the company does not give the possibility to other companies to use data to offer additional services. Some sporadic cooperation has been done with other entities, but not yet considering the possibility to give them freedom on the services.

A step forward in the TO-BE state can be made from the service provider deciding to partner or open the platform to other actors. This will allow companies to use this data to offer complimentary service. For example, considering only product data, the supplier of consumables may offer a forecast of the needed quantities according to the usage (9), and at the same time, he can use it to plan his production.

To move on the "*decision ownership*" dimension in the framework, the company should approach service provision proactively and thus, after data are analysed, act for the customer who completely delegates some activities to him. Moreover, if other actors are involved in the service provision, they can directly take responsibility for the service. For example, again considering product data, if the manufacturer is now able to define when maintenance is needed and there is an agreement with the customer, he should act proactively to offer the service (10). In the same way, the consumable provider may manage the direct provision of consumable on customer need (11). This step not only requires the need of data visibility from the party that should deliver the service, but also a structured back-office and resources that are able to monitor, interpret information and perform a proactive service in an efficient and timely way.

Another consideration to enlarging service portfolio and the solution itself is on the data source dimension. Indeed, the actual offer considers data coming from the product and operations, with the integration of some external data Nevertheless, many times those data are not enough to provide interesting insight, considering that many data are independent between them. In this view, the company may work to give the possibility to customers to connect and integrate enterprise data, that may be for example the ones regarding production, quality, energy prices or space occupancy (see Table 30). This would allow the manufacturer to expand the service scope and ideally move towards different service levels as described above. Considering the complete set of information available, the company may reach a complete understanding of the customer and may be able to reach more value-added offerings. For example, they can perform energy performance analysis in accordance with the customer's production plan (12), or they may be able to offer optimisation algorithms to suggest to the customer the best wat to plan production limiting the energy expenditure (13). Considering, instead, third parties, one possible service that is clearly addressable is the one of energy trading (14). In the same way, those new services have been proposed, it is possible to proceed forward and try to cover all the blank space in the graph.

Table 30 - Case 7 “Data source TO-BE”

Data Source	Description
Enterprise	Enterprise data may represent data related to the customer production processes, both considering data on machinery efficiency, quality of the final product, machine parameters, operators and so on. Data on energy contracts of the company may also be considered in accordance with different parameters such as penalties and not only considering the cost of energy consumption.
Contextual	Interesting external data, in this case, are weather data, that can impact both on the energy consumption and the decision related to the installation of renewable sources. Regulations and certificates for all the different region in which the service may be deployed represent another external information to be collected and considered. Energy prices can also be included in this category in the case energy is purchased from open energy market

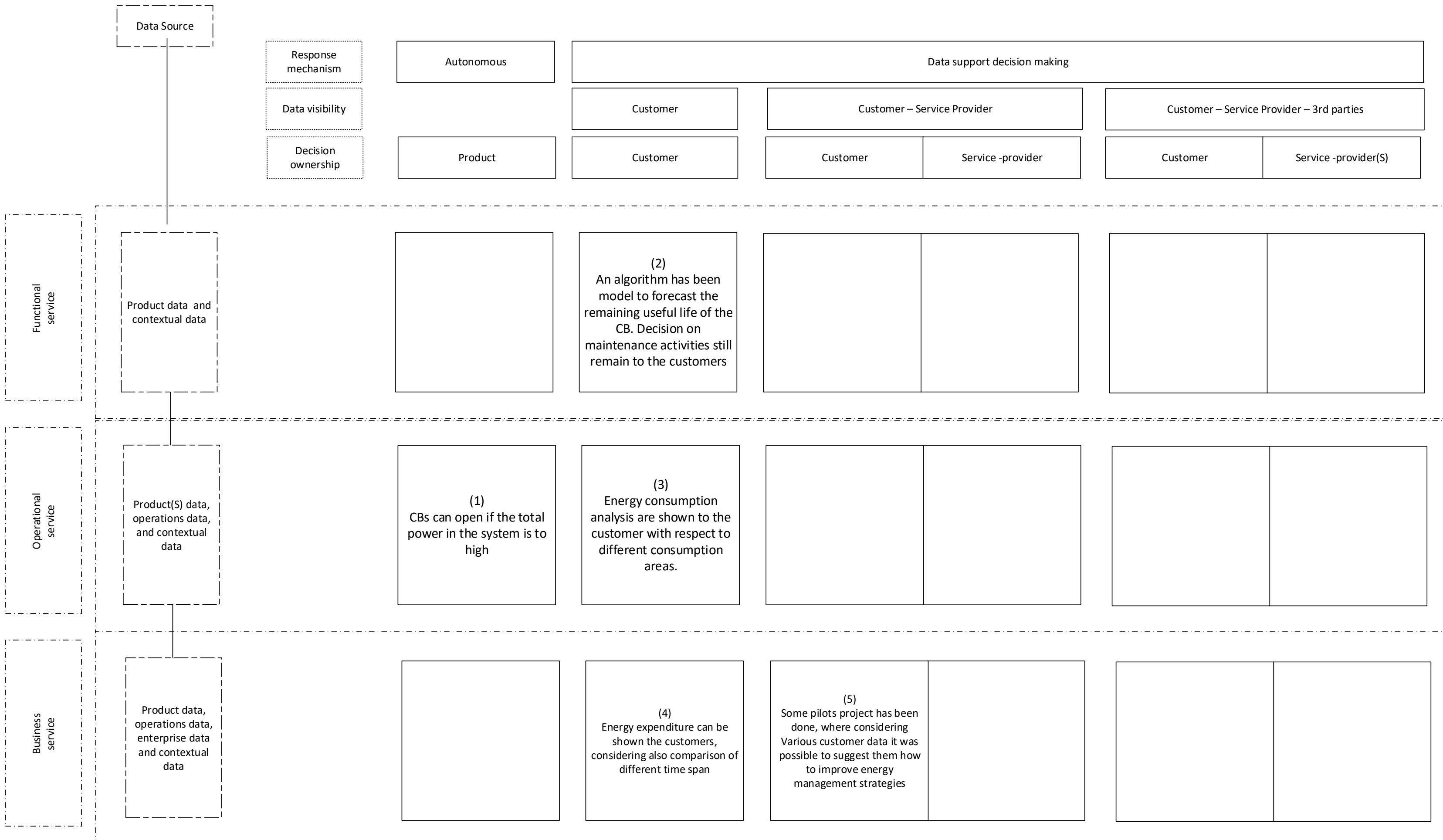


Figure 33 - Framework map CASE 7 AS-IS

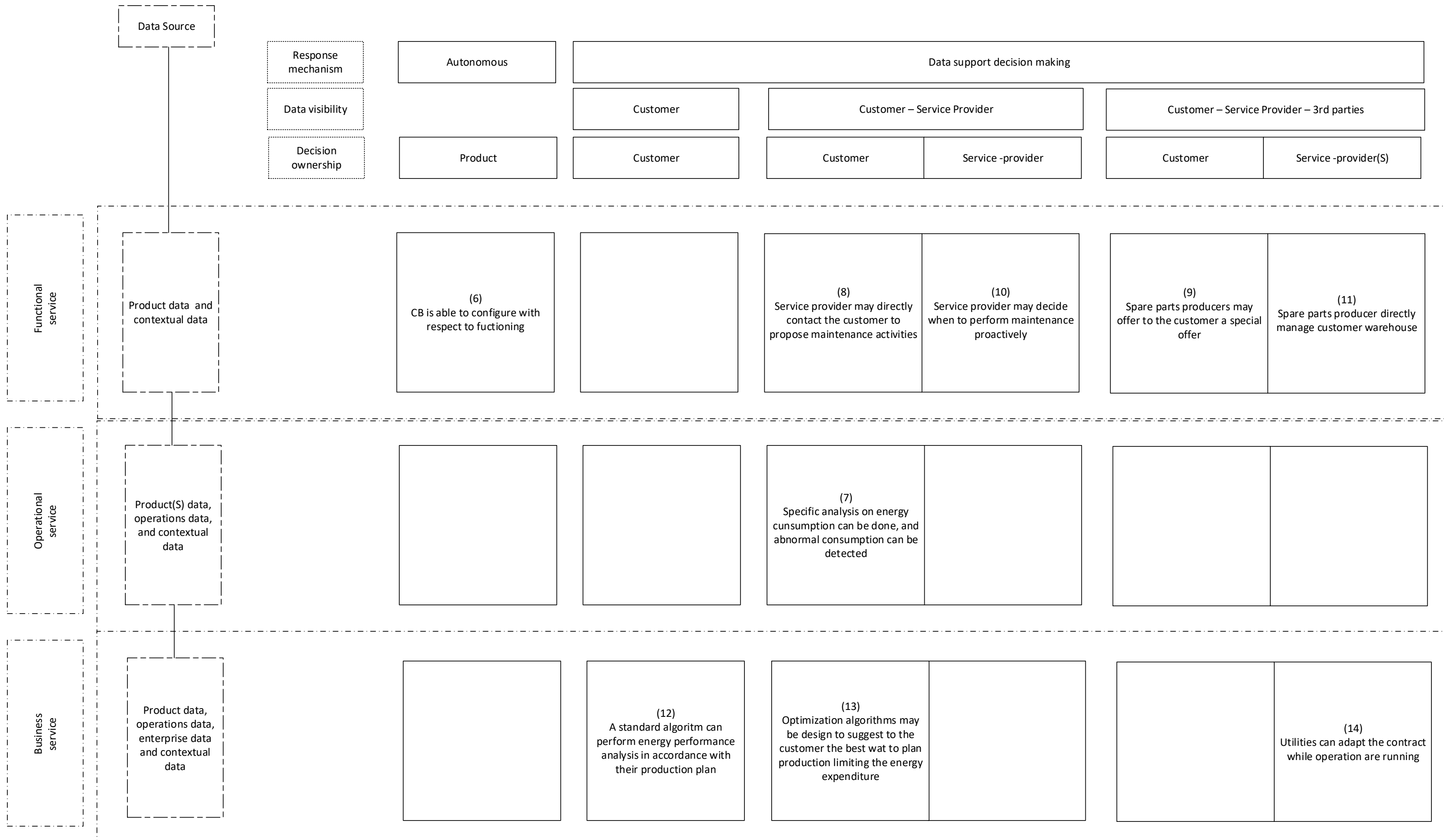


Figure 34 - Framework map CASE 7 TO-BE

7. RQ1 Outcomes

This chapter aims to answer RQ1:

Which are the characteristics and specific features of DDPSS that differentiate them from the traditional PSS?

This chapter contributes to the definition of key characteristics of DDPSS, defining a comprehensive vision of the possibilities that data collection at the customer location and the utilisation of analytic tools may create in a manufacturer offering towards Servitization, by mean of a two-hierarchical conceptual framework. The framework has been defined by taking into account the perspectives of relevant research into the digital Servitization and has been validated in practice. Analysing relevant paper in the context, it proposes four dimensions as the necessary characteristics needed to describe and categorise them, that are *(1) Data Source (2) Data Visibility, (3) Response mechanism and (4) Decision Ownership.* The applicability of this framework has been tested in practice and therefore provides a basis for future research. Indeed, multiple case studies show how all different offers can be included and described trough the framework, ensuring the completeness of the predefined dimensions.

This framework provides a twofold contribution: on one side, an academic contribution is offered with respect to the synthesis of previous research and the definition of a common understanding of the characteristics of those service solution. On the other side, the framework also resulted in an actionable tool for practitioners, since it provides them a guide that was not present before, which enables them to map their actual portfolio of DDPSSs and try to think about additional offers by looking into the spaces of the framework that are not cover yet, as demonstrated in the application case.

The framework considers characteristics that are related to the specific domain of data included in the service offering. At the same time, it does not take into consideration either technologies that enable the realisation of the DDPSS and the business models that may be used to reach the customer or feasibility analysis. In fact, the technological decision may limit the possibility to explore some of the levels of the presented offer, and on the other side, the same technologies may enable manufacturers to introduce innovative business models. Indeed, the possibility to monitoring the real status of products, take action for the customer and provide prescriptive analytics enable DDPSS provider also to rethink the way they reach the customer, supporting, for example, pay-per-use contracts or payment on cost-saving.

VI. DDPSS SE METHODOLOGY

1. Objectives

The capability to connect products and collect data from them is completely reshaping the PSS concept. PSS offerings are becoming complex: from the manufacturing side, offering such solutions requires not only technological advancement but also new knowledge and new approaches. Smart connected products enable the manufacturer to enter the customer processes and offer completely new services, redefining relationships with customers. Moreover, the impact of data availability extends to the entire value chain. This adds a new level of complexity to the manufacturer's transition towards PSS provider that was not present before. The large amount of data generated both from users and products is recognised as the key for value creation, if effectively approached with the right data analytics tools (Rymaszewska, Helo, and Gunasekaran 2017b). Indeed, data availability challenges methodologies and tools, since new services not only have to "deliver information efficiently", but "create valuable information" for different users (Sambit, Vinit, and Joakim 2016). Given that, practical approaches should be adopted from manufacturing companies to leverage new revenue streams from data analytics (Opresnik and Taisch 2015).

According to a recent study, it is possible to notice how the Service Engineering domain is mostly devoted to the traditional PSS design methods and Traditional PSS (Pirola et al. 2020). Some recent studies give first attempts to formalise Smart PSS design (Zheng, Lin, Chen, and Xu, 2018; Watanabe, Okuma, and Takenaka, 2020) and few studies tried to relate and verify the validly of traditional PSS Service Engineering (SE) methodologies in accordance with the recent digital advancement (Hagen, Kammler, and Thomas, 2018).

In particular as highlighted by Pirola et al. 2020, the evolution of PSS design in relation to the digitalization trend is concentred on two different perspectives: on one side they are related to the evolution of the design content, that shifted from traditional PSS to "smart" PSS, and on the other side, works are related to the advancement of methodologies and methods adopted to design PSS. Specifically, it is possible to notice:

- Works focused on transforming technology into a PSS business model for example considering RFID as a service or Big-Data as a service (Michael et al. 2010; Espíndola et al. 2012; Marini and Bianchini 2016).
- Works that try to design new PSS based on technology, integrating CPS and PSS from the early design stage, to generate intelligent integrated solutions (Wiesner, Marilungo, and Thoben 2017, Michael et al. 2010).
- Methods to design data-driven PSS (Exner, Stark, and Kim 2018). They are mostly related to traditional methodology and to PSS requirements definition (Z. Wang et al. 2019) or the adoption of product-oriented design methods (Z. Liu et al. 2020; Z. Liu, Ming, and Song 2019; Legault et al. 2019; C. H. Lee, Chen, and Trappey 2019; Kammerl et al. 2016)
- Few attempts intended to use smart and digital technologies as enablers to define innovative methods or tools to design PSS or smart PSS (Lützenberger et al. 2016; Kammerl et al. 2016; Hara 2018), mainly focusing on a better understanding of the customer needs from the early design stage.
- Study on specific data analytics methodologies, such as ML and AI in the design of PSS (Abramovici et al. 2018; D. Chen et al. 2019; Chowdhery and Bertoni 2018) with particular attention to the early stages and customer feedback collection.

In general, few papers consider the adoption of Industry 4.0 technology either in the solution and in the design methodology and real applications are still missing (Pirola et al. 2020). Moreover, scarcely any work provides overall inclusiveness of DDPSS characteristics and they tend to focus on technological aspect and innovations. There is a specific demand for new methodologies concerning the use of customers operational data that are gathered from embedded sensors, e.g., from SCP, but also from distributed sensors at the customer location, considering specifically cloud-based solutions. Furthermore, is has been clearly stated the demand for new approaches to generic processes and methodologies for the early stages of the engineering phases (Kuhlenkötter et al. 2017).

To address the above consideration, the presented chapter aims at supporting manufacturing firms in their transition towards servitisation by proposing a methodology that guides them, covering the second gap defined in Chapter III (Figure 23).

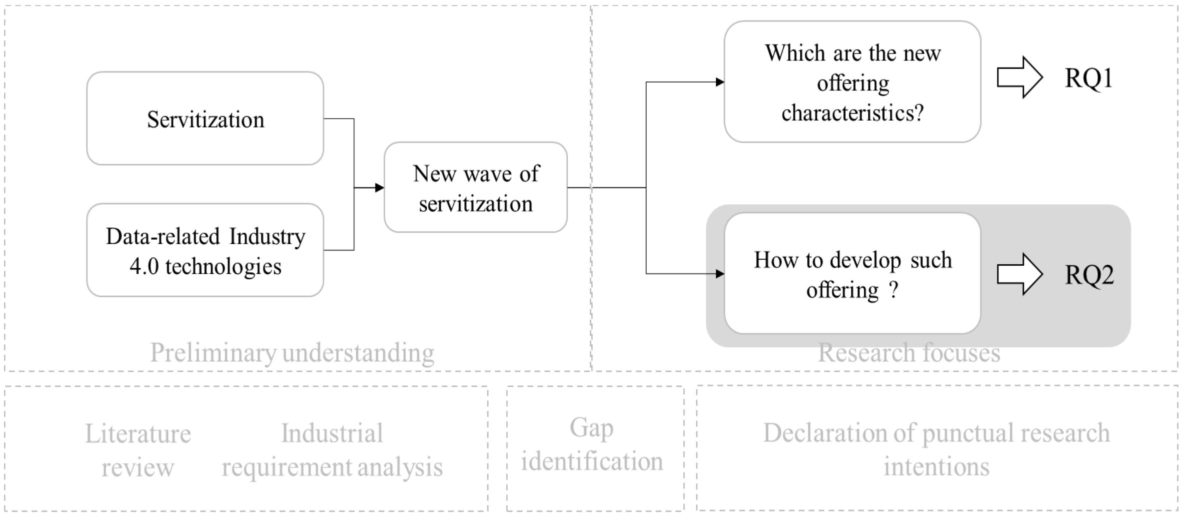


Figure 35 - Contribution of the presented Chapter in accordance with the identified gaps

The methodology is specifically designed for B2B services, that are enabled by new technologies and data. As previously discussed in the introduction, the need for a new methodology is emerging for this type of services; and considering the previously defined gaps, the presented methodology included the following dimensions:

- Expansion of the service scope creates the need from the manufacturing side to understand customer context and rules in fields that may differ from the ones related to the product;
- The availability of data requires the manufacturer to transform raw data into information and actionable insights in order to deploy new data-driven services;
- Software and cloud-based environment represents a new paradigm for the manufacturer's culture, in addition to the service mindset;
- Modularity and reusability principles represent a valid way to develop standard but customised solutions for different customers. Therefore, solutions should be thought as independent modules, that can be easily put together in different scenarios;
- The value chain reshapes, since new relationships emerge both with the customer and with other partners, redefining how value is created and shared among actors.

2. Methodology

The methodology developed has been firstly inspired to the SErvice Engineering Methodology (SEEM), an existing design methodology developed in the author's research group, which represents valid support for the development of traditional PSS, considering both the customer and the service provider profitability of the service offer (Pezzotta et al. 2014). Specifically, as shown in Figure 37, the "new SEEM" methodology shifted the initial version, which is dedicated to traditional PSS design methods and Traditional PSS, to a new dimension, that considers Smart enabled methods for PSS design and Smart PSS, only dedicated to DDPSS. The need to investigate this new dimension and propose new methodologies is clearly emerging since existing tools and methods do not comply with the requirements of smart PSS design and the intelligent approaches for the development of Smart PSS are still scarce, not including real applications (Pirola et al. 2020).

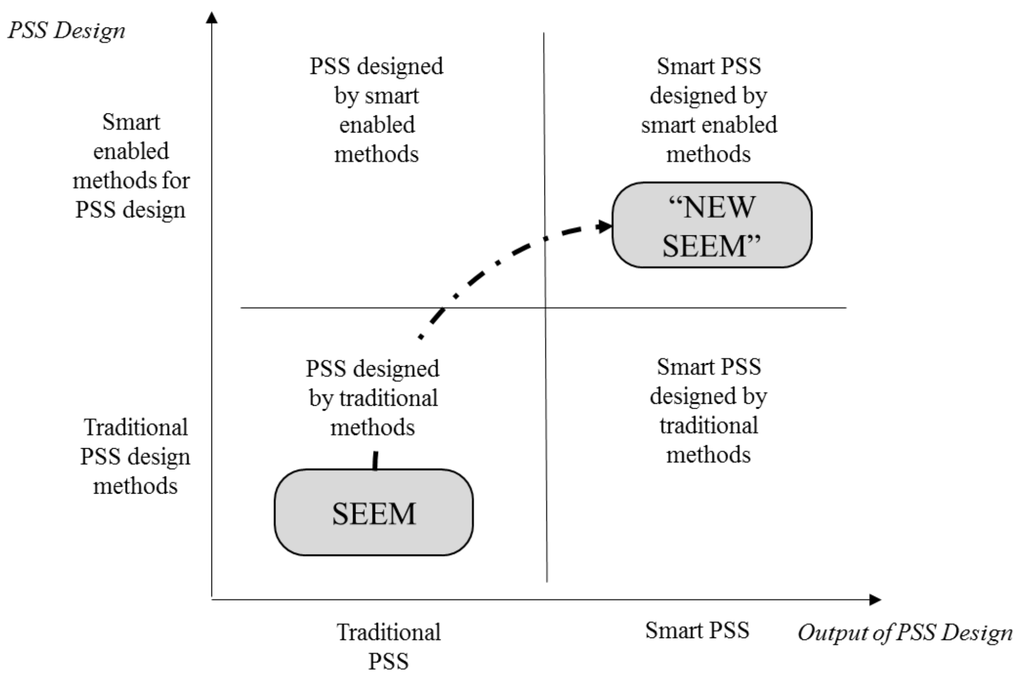


Figure 36 –Evolution of SEEM contextualized in a PSS design framework by (Pirola et al. 2020)

The SEEM presents barriers when applied to DDPSS, tush it required to make some changes. The changes have been made taking into account both the necessities that emerged when considering the DDPSS characteristics and peculiarities, and reflecting on the recurrent phases into the PSS engineering domain, which are: 1) customer analysis, 2) requirements analysis, 3) PSS design, and 4) PSS test (Pezzotta et al. 2014).

The Service Engineering Methodology presented in this chapter, and the differences with respect SEEM, are also the result of a three-year collaboration with the ABB company, following the activities related to the development of new DDPSS, where the generation of new knowledge into this direction has been a mutual task and a learning process. Indeed, the methodology has been evolved over time, through intensive collaboration between the researcher and the ABB digital team, following specific pilot projects but also observing every-day activities and processes as well as methods and tool already present in the company. Therefore the process followed in order to achieve the result can be classified as an action research approach (Gummesson 2000), as already explained in Chapter IV.

An ultimate version of the methodology has been then defined and used into an application case, developed on harvested experiences. Moreover, a final validation has been performed with different possible users of the methodology among ABB employees. Specifically, a workshop session has been carried out, presenting the overall methodology, the different phases and methods proposed, both from the literature point of view but also by means of examples and an application into their context. A structured form has been designed for all of the participants to evaluate the clarity, completeness, consistency and usability of the proposed DDPSS SE methodology.

3. SEEM

The SEEM has been developed to support the engineering and reengineering of suitable and complete PSS solution to increase the company's competitiveness and profitability, focusing on two main areas: the customer and the product-service provider.

It considers four different phases: (1) customer need analysis, (2) Process prototyping, (3) Process Validation and (4) Offering identification and analysis. As a starting point, the methodology has been used to develop a DDPSS. Nevertheless, the main challenges emerged considering the company sphere; indeed, as it is possible to notice, from the company point of view, the methodology is mainly focused on the prototyping and validation of a service delivery process, which is no suited for the representation of the data-related services developed and deployed on data analytics, software and automatic response. DDPSS diminish the need for the co-location of customer and provider and enables the provider to deliver services over long distances, for a significant part of the overall service. Moreover, when based on automation, they require the standardization and storability of service delivery processes. (Schumann, Wünderlich, and Wangenheim 2012)

Overall, as for the other traditional PSS engineering methodologies, it does not consider some main features of DDPSS services, which are: (i) enlargement of service scope, (ii) data transformation into information, (iii) software-based solutions, (iv) reusability principles and (v) value chain perspective.

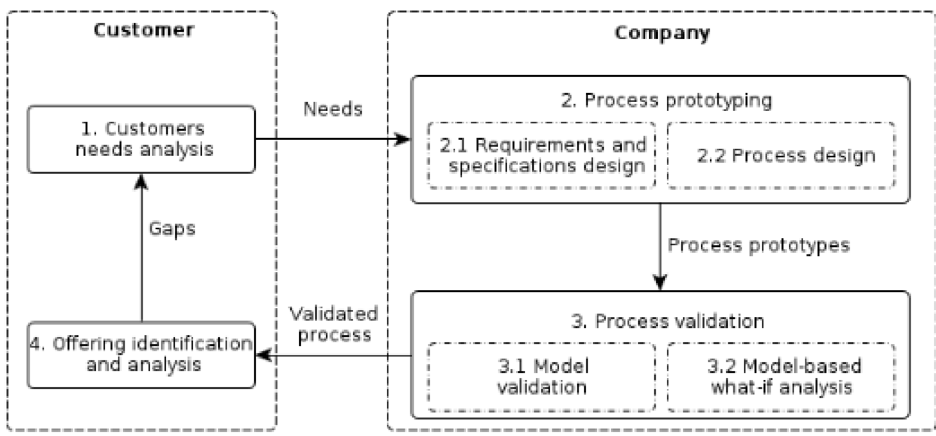


Figure 37 –SEEM (Pezzotta et al., 2014)

4. DDPSS SE Methodology overview

As shown in Figure 38 the DDPSS SE Methodology is based on seven phases, which are (1) definition of service scope, (2) customer need analysis, (3) requirement analysis, (4) competitor analysis, (5) PSS design, (6) technical assessment and (7) value assessment, that are in some cases further decomposed into sub-phases.

The different phases have been derived from the most recurrent phases into the PSS engineering domain, considering the ones that were also suitable for DDPSS: 1) customer analysis, 2) requirements analysis, 3) PSS design, and 4) PSS test. Based on them, data-driven peculiarities have been included, resulting in the “definition of the service scope” and the “data module” within the PSS design. Moreover, by matching them with the industrial needs, the solutions evaluation and selection phase has been added, both considering customers and value chain benefits.

For each of the different phases, one or more methods have been proposed and adopted. Indeed, a *methodology* recommends the general strategy to solve the problem and usually identifies the *methods* to be used in it, which entail how an approach will be practically implemented and encompassed how a phase would be achieved (Andiappan and Wan 2020).

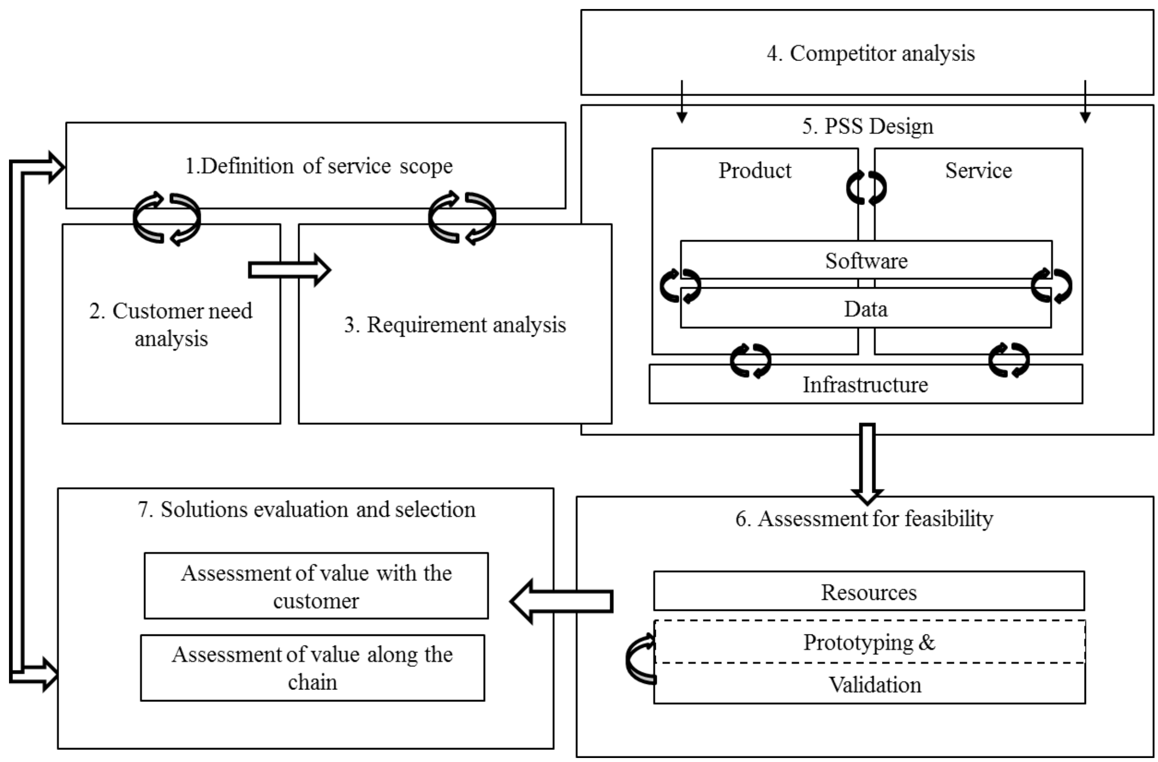


Figure 38 – DDPSS SE Methodology

The structure of the framework also follows the basic pattern of one of the most acknowledged models of the project cycle, which is the “V-Model”. The “V-model” has been proposed in the context of System Engineering (Kevin Forsberg 1994), and it is used in different branches such as software engineering (Easterbrook 2001) or requirement engineering (Dick, Hull, and Jackson 2017). The model represents a sequential path of execution of a process. On the left side of the "V shape", decomposition and definition of requirements succeed one another, and each phase has to be completed before the next one begins. On the right side of the "V-shape", is represented the test plan that has to proceed with the development, with a corresponding phase for each of the ones on the other side.

In this work, the researcher adopted the same reasoning to the PSS domain. As it is possible to notice, the "V-shape" in the presented methodology is rotated as it is shown in Figure 39. The definition and decomposition of requirements descend in the upper part of the methodology from left to right, while integration and verification follow in the lower level from the right to the left side. Starting with stakeholder requirement on the upper left, it ends with a user validation of the system at the down left side.

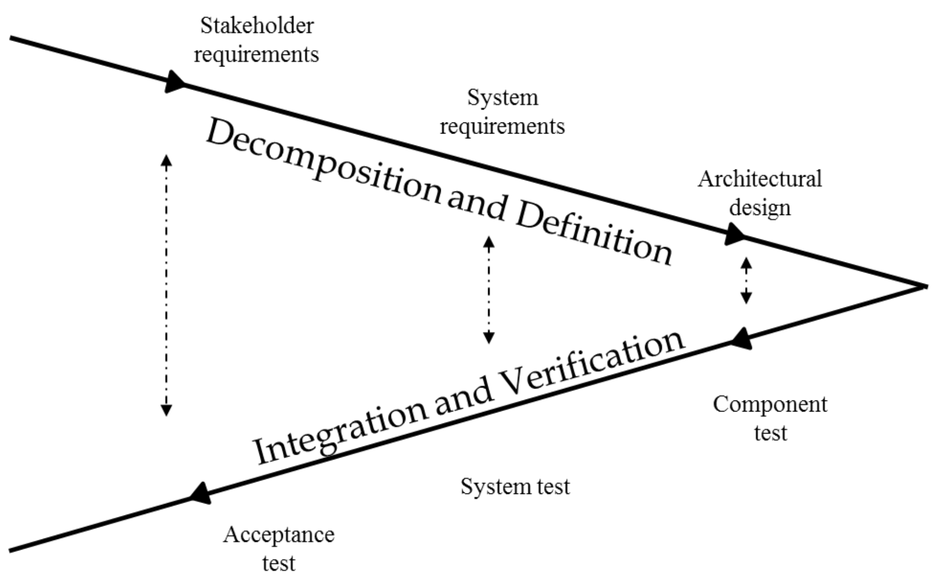


Figure 39 – Underling "V structure" in the DDPSS SE Methodology

4.1. Phase 1: Definition of service scope

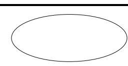
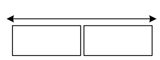
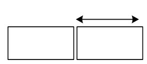
As a preliminary step, the manufacturer should realise which is his existing network and decide a specific actor he would like to address with new service. Starting from a situation in which a manufacturer aims to leverage data collected from customers, the first scenario to consider is the one in which the manufacturer maintains a central role and aims to provide new services to traditional customers. The scenario considers that products communicate data to the manufacturer's platform, from where he is able to analyse data and deploy services based on them. The scenario has been selected as the first to address since the first sources of data that this research aims at considering are the connected products at customer location during their Middle of Life (MOL). This data can be leveraged to offer advanced services for the customer at first and consequently for other actors too. Moreover, this scenario includes explicitly the challenges for the manufacturer to understand the customer's environment.

The first point to address is to foster the perspective of the manufacturer to think beyond the boundaries of his traditional service and try to consider new possibilities. The service provider needs to clarify the role of the product in the customer settings and try to identify general relationships between the product and the context of use. This is useful to understand if it is possible for him to broadening scope and services offerings. In order to achieve this understanding, the development of a ***conceptual model*** is proposed as a means to understand relationships. Indeed, a conceptual model can be used for explanatory purposes, to promote greater understanding or insights by others into the phenomena of interest (Thalheim 2011). It can depict an explanation of *how*, *why*, and *when* things happened, relying on varying views of causality and methods for argumentation. ***Object Role Models (ORM)*** have been recognised as a suitable means to represent and develop the conceptual model. ORM results particularly suited for the aim of considering the simplicity of building, representation, communication, and utilisation from people that are not confident with modelling techniques. Indeed, it analyses a domain in terms of elementary facts that assert that an entity has an attribute or that one more entity participates in an association. The relationship with entities is defined by the roles in the association (Kristensen 1996). Moreover, for the predefined purpose, the essential feature of the modelling language will be used.

Concerning the scenario proposed, the model should represent the role of the product contextualised in its working environment, considering the part it plays and possible areas of influence. The representation should give a comprehensive overview of what the product may reach, directly and indirectly in terms of systems, actors and decision they can make. For an explanatory purpose, Figure 40 reports a general representation of the considerations that the author suggests to develop the conceptual model, using the ORM components reported in Table 31. The representation is not meant to be exhaustive for all relationships but provides directions on the most important ones to include and guidance of the necessary consideration to develop a conceptual model. The conceptual model should start considering the product and its main role in the context where it usually operates. Entities should be defined starting from the (i) **product** itself, and they should include at least (ii) the main **activities** related to the product (e.g. maintenance activities, settings) and to what/who interact and (iii) **system** in which they operate. Subsequently, an essential aspect of concerns (iv) **decision**s that can in some way impact something directly or indirectly related to the product and then internal and external factors such as (v) **rules,** (vi) **contingencies, or** (vii) **regulations** that may impact on those decisions or activities. Moreover, the conceptual model should include entities that represent different (viii) **roles** in the companies, from operators to managers, that interact in the context. Specifically, for this last point, the model proposes also to organise the representation of human actors on one side of the model, in order to make them emerge immediately since they may represent possible users of the new service solutions.

Between entities, different types of associations can be drawn that should be representative at least of ***belonging, interrelations, impacts*** *and* ***decision power***.

Table 31 – ORM legend

Symbol	Description
	Object or entity
	Roles, binary association
	Roles, single association

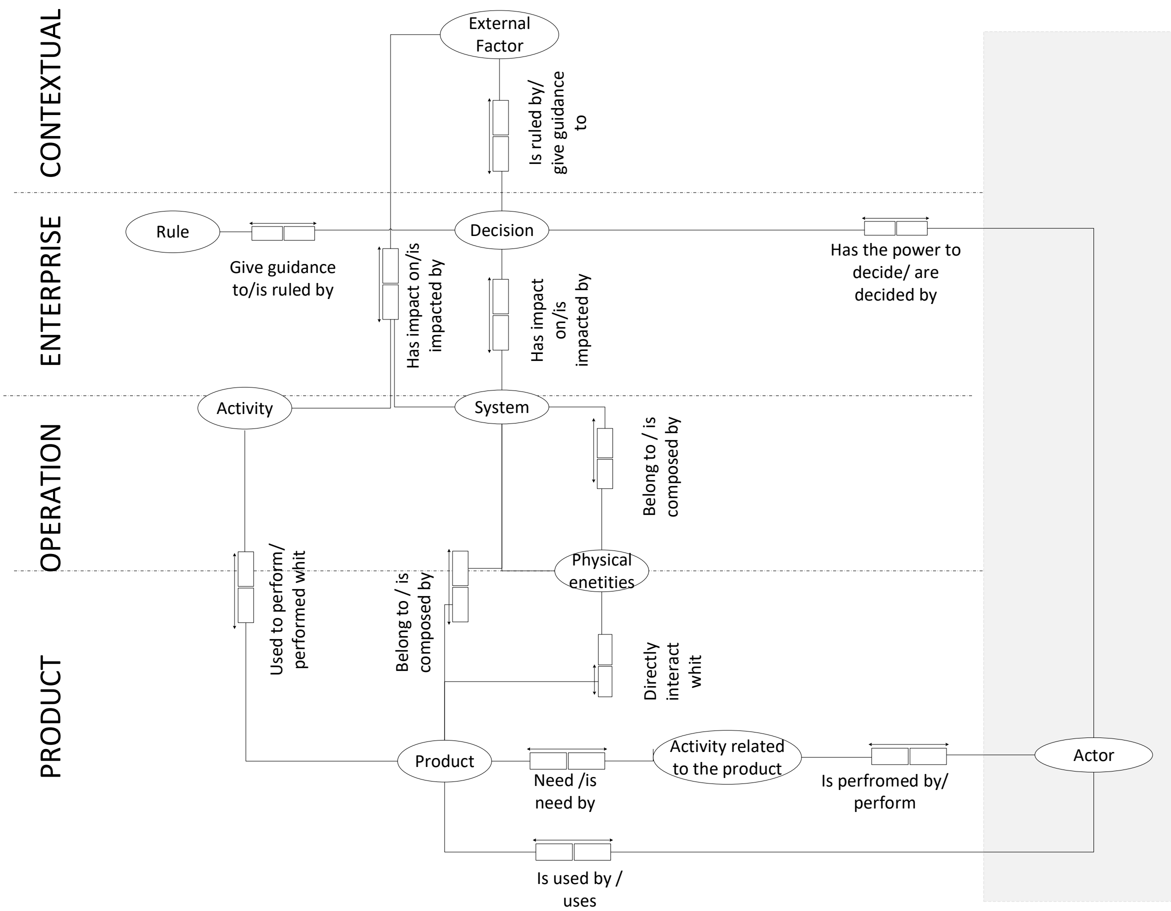


Figure 40 – Conceptual model with minimum entities for the “service scope definition” purpose

The model should include information of the customer context, and the researcher suggests to graphically organise different entities identified according to four main layers, that have the same meaning as defined in chapter V: *Product(s), Operation(s), Enterprise and Contextual*. This way, the conceptual model fosters the service provider to organise thoughts systematically and understand both the domains that can be potentially covered with the new service offering and where the data should be gathered. The level of detail of the conceptual model should be defined by the users, i.e., the service provider and customer. However, generally, it is a good practice to try to go as deep as possible, and then decide to exclude some areas based on different reasons that may vary from technical infeasibility, lack of competences, avoid to enter in a highly competitive market, absence of profitability for the provider or value for the customer end so on. This initial selection is not mandatory, and it is subject to manager reasoning and company strategies. At the end of the Phase1, the manufacturer should be able to define a clear scope considering the four perspectives represented by the four different layers. Within each of them, possible service areas should emerge. For each layer, multiple areas may exist and some areas may cover some parts of different layers.

4.2. Phase 2: Customer needs analysis

Phase 2 defines the customer needs according to specific customers typologies that may share the same service. ***Persona development*** is a recognised tool in both product and service development but also in marketing and other disciplines. The purpose of persona development is to create, from a user-centric perspective, hypothetical user profiles using characters that have general names and characteristics, conveying a wide range of qualitative and quantitative data. Data can be gathered from customer databases and through ethnographic methods such as interviews or observations (Pruitt and Grudin 2003) and they usually lead to the identification of different persona profiles (Cooper 1999). Personas typically include general variables such as demographic and behavioural, but also general information, like the environment, necessities, and goals (Stickdorn, Hormess, Lawrence, and Schneider, 2018) creating a set of well-defined characteristics that help make the needs of customers salient and intelligible. To perform a better analysis concerning the context developed in Phase1, this methodology suggests defining different personas according to the different identified areas that the service may address: they may vary consistently since different offers are perceived differently from the market. This phase should lead to the definition of customer needs, that are expressed, as in (Pezzotta et al. 2014) as "*the customer necessity, in terms of the results of the expected service and/or performance*". A general example of a customer need can be, considering a manufacturing firm, maximise plant availability.

Phase 1 and 2 are recurring, and after the definition of a more specific persona, the customer context should be refined accordingly.

4.3. Phase 3: Requirement analysis

Phase 3 follows the principle approach of SEEM to transform customer's needs in service solutions, so-called the Service Tree. The approach has been modified including layers referred to the definition of requirement and proposing some supportive tools to adopt in the development. The overview of the tree is depicted in Figure 41. This tool supports the representation of needs previously identified into the persona analysis, and the definition, for each of them, of how they may be satisfied, and the solution that may be deployed to the users, employing the "***job-to-be-done***" approach and using "***Cause-effect diagram***" in the cases that more and in-depth analyses of causal relationships are needed. In the following, a more detailed description is presented, also considering the link that has been added between the elements of the Service Tree with the general requirement layers proposed by Dick, Hull, and Jackson (2017) as described in Table 32.

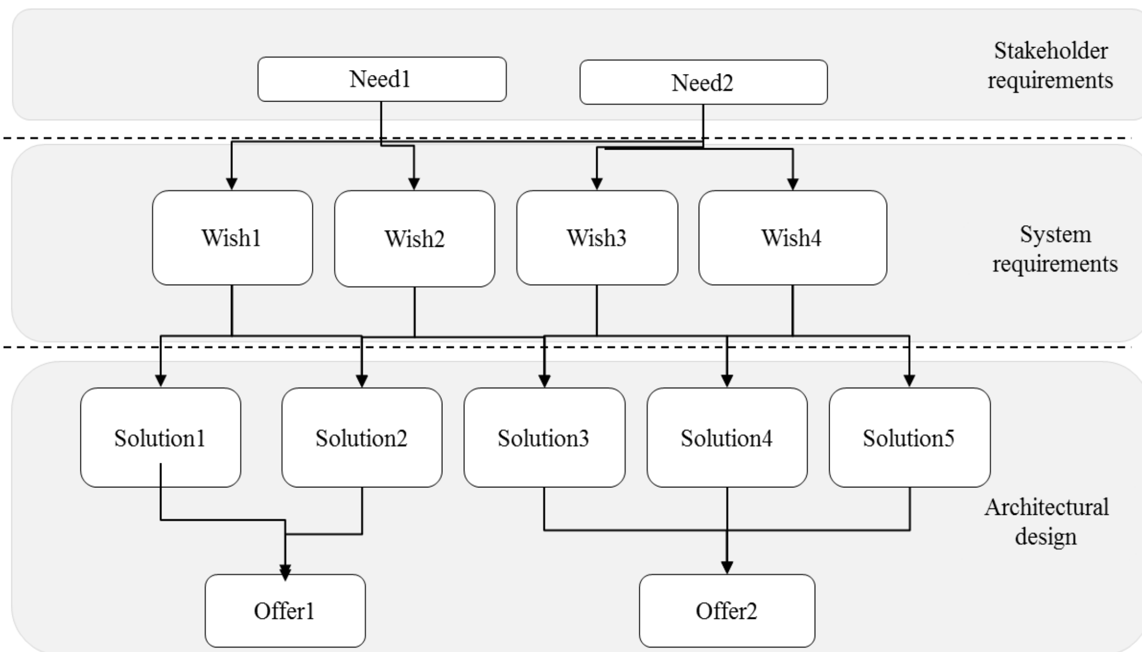


Figure 41 -DDPSS Tree

Table 32 – Requirements (adapted from Dick et al., 2017) and Service Tree terminology (adapted from Pezzotta, Pinto, Pirola, and Ouertani, 2014)

Requirements layer	Role
Stakeholder requirements	State what the stakeholders want to achieve through the use of the system. Avoid reference to any solution
Need	The needs are customer necessities, in terms of the results of the expected service and/or performance

Requirements layer	Role
System requirement	State abstractly what the system will do to meet the stakeholder requirements. Avoid reference to any design
Wish	How customers' wish to satisfy their need
Architectural design	State how the specific design will meet the system requirements
Solution	Identify a possible solution that the company can deliver to fulfil customers' wishes and needs (it may be composed by one or more sub-systems, that are: Product, Data, Service, Software and Infrastructure)
Offer	The final offer is the set of solutions that the service provider can release on the market in the form of a bundle

As already introduced, after the previous analysis ***needs*** should be understood and they should represent, as in the SEEM, the customer's necessity in terms of the results of the expected service and/or performance as well as represent the **Stakeholder Requirements**. They describe the goal that a customer wants to achieve without defining any solution. In general, different customer segments display different needs or emphasise the same needs in different ways. Needs can be generally defined, but they should aim at covering all the areas of action that have been identified in the first phase. That level of analysis, indeed, is useful in needs identification and also starts to provide input to the definition of customer wishes.

Wishes express how needs may be satisfied. Considering, for example, the need to "reduce costs", the wishes can be translated in "reduce breakdown time" but also "reduce energy expenditure" or "optimise energy supply strategy", defined accordingly to different layers of the analysis. Wishes can be further decomposed into sub-wishes if required to clarify their content better. All different wishes and sub-wishes contribute to the definition of the **System Requirement**. They do not include solutions yet: they start defining how stakeholder requirements can be satisfied. The ***Jobs-to-be-Done approach*** (Christensen, Anthony, and Roth 2004) is here proposed as a suitable method for the identification of wishes; indeed, it is proposed in the methodology to define customer activities in the current situation, including different types of information: a general description of activities, decision-making processes and difficulties, with the aim to identifying necessities and gaps in the customer routine and for exploring potential solutions. Considering the fact that a product or a service usually perform or provide support in specific activities (job), this approach proposes to investigate jobs that users need to perform since they provide insight on what an individual really seeks to accomplish under a given circumstance. Usually, goals can vary from little and simple jobs to big and complex ones involving different task. Understanding which is the progress that the customer would like to make will help in designing possible solutions (Stickdorn and Schneider 2010). The job-to-be-done approach is usually adopted into Value Proposition Canvas (Lindič and da Silva 2011) which support the understanding of the things that people are trying to do considering tasks they have to perform, problems they need to solve, or needs they try to meet. It is suggested to define personas accordingly to customer segments levels and subsequently define the different jobs in accordance with users identified within the customer segment. Indeed, even the general service is aimed at a customer, the final consumer of the service can be an actor.

It has been already stated that individuals within customer organisations often perceive value in different ways. Especially, in a B2B context, customer value can be divided into benefits perceived at the organisational level, and benefits perceived at the individual level (Macdonald et al. 2011). Nevertheless, in the context of DDPSS, a service provider should jointly develop a solution aimed at satisfying a customer need such as minimise expenditure, by implementing a solution that is perceived by the final user as valuable. For example, the solution can help users in the identification of a fault and save them time while concurring at a higher level in cost-saving. Cases in which high-level objectives are not aligned with one of the customers may exist, but resolution between trade-off will be not covered in the present research.

The conceptual model created in Phase1 is useful for both the definition of customer characteristics for Persona Development and to identify users to include in the job-to-be-done analysis. Furthermore, since one of the main potentials in data-driven services is to support the decision-making processes, customer needs should be representative of those processes, considering both decisions to be made and the execution of activities. To this end, customer jobs should be thought and divided into different categories, according to the general classification of decisions levels, such as: strategic, tactical and operational (Harrington and Ottenbacher 2009). Strategic decisions are the ones related to an organisation's strategic ends and are closely related to the mission, goals and objectives of the firm. Tactical decisions are concerned with an organisation's strategic means or “how” the firm implements achieving its ends. They may be represented by action plans, policies and procedures. Operational decisions are those that impact daily operations in functional areas of the firm (Brews and Hunt 1999).

After the definition of wishes, solutions need to be designed. ***Solutions*** represent the final answers to a customer need and the associated wishes. Translating wishes into solutions can be a difficult task, and the conceptualisation of a solution may require rethinking or redefinition of wishes. In order to better define wishes and solutions, the proposed methodology suggests the adoption of methods that stimulate rational thinking like a ***cause-effect diagram***, to help understanding real factors that can address the service scope. In this phase, the job-to-be-done needs to be analysed again, since for example considering the need to “reduce costs”, and the wish to “reduce energy expenditure”, there may be several factors affecting them and different actors may go in the same direction. Therefore, users usually need support in more practical jobs or decisions that all concur with the cost reduction for the company. Moreover, some factors may not be known from a service provider, specifically when defining offers that exceed the classical extent of the manufacturer know-how. In those cases, the customer involvement may be not enough to achieve a concrete solution, since he also does not really know the solution he wants, or he does not perceive the complexity under a specific area. An ***expert in the contextual domain*** is needed to clarify exactly specific possibilities and constraint.

Concluding, solutions should also be guided from ***technological input***, considering the new possibilities that emerge in the context of autonomous solutions provided by new hardware functionality and technologies available and on the other side by the possibilities that data analytics brings, such as the possibility to provide descriptive, predictive or prescriptive tools to a customer. The ideation of solutions is directly linked with the **Architectural Design** phase, which defines how the service provider will satisfy the customer with his resources. This last layer goes directly into the design stage, which explain why phase 3 and phase 5 overlap in Figure 38.

Table 33 summarises the tools and techniques proposed to support the different phases of the requirement elicitation and accordingly, the elements that are included in the service tree.

Table 33 – Steps contribution in the service tree

	Service Tree		
	Need	**Wish**	**Solution**
	Stakeholder requirements	**System requirement**	**Architectural design**
Tools and techniques			
Contextual Conceptual Model	X	X	
Persona development	X		
Job-to-be-done		X	X
Cause-effect diagram		X	X
Domain expert		X	X
Competitor analysis			X
Technological input			X

4.4. Phase 4: Competitor analysis

Phase 4 is concerned with the analysis of the competitive landscape. It has been positioned before starting defining the final offer and after having defined the customer' desired solutions since it enables the manufacturer to have a clear overview of the already existing solution, if they are successful, if there are cases of failure, and how much their offers can be differentiated from the ones of competitors. This phase does not propose specific methods; indeed, it is well-established, both considering processes and methods proposed by academics (Hatzijordanou, Bohn, and Terzidis 2019) and companies' practices. The recommendation is to perform the analysis considering again the service scope defined in Phase 1, since according to the different levels the types of competitors emerging may be different from the ones that are traditionally considered as competitors for the manufacturer. The methodology suggests defining possible new and traditional competitors and performing an analysis of the offers, with particular emphasis on the ones related to the data domain. A typical example in this context is system integrators, who now owns the competences in order to collect data from different sources and gather them into a customised interface. Usually, their limit is concerned with the high cost of implementation and the fact that they will not take care of possible service offering that can emerge from data.

4.5. Phase 5. PSS Design

The definition of solutions is part of the design phase, in which the requirements of the customers are translated into effective product functionality or characteristics, data visualisations and so on. More specifically, at this stage, solutions are defined considering different elements. A DDPSS may be composed of different sub-systems:

i. ***Product.*** The first benefit that is provided to the customer is the product. The offering of new data-driven services may require rethinking the product and make changes to them, such as introducing additional sensors and actuators. Also, hardware retrofitting solutions can be developed to enable the deployment of new services to old legacy products.

ii. ***Data***. This is the core sub-system of data-driven service. Data need to be transformed into information and insights to support customers activities and decisions. All those applications are mainly deployed through the platform to the customer.

iii. ***Software***. In order to support data analytics, specific software development needs to be considered. Software requirements include both the front-end platform for the customer as well as the supportive back-end platform for the service provider.

iv. ***Service***. Not all the solution or the complete offer should be performed through a platform or a software tool. New services may require different action that the service provider has to perform both for the correct functioning of the entire solution or to take care of the delivery of actions. Specific service offering can include:

a. *Study of the relevant point to connect:* When more products are located or sold to the customer side, a necessary step is to understand if all devices need to be connected. This analysis changes with respect to the different applications, and is an important step that can be required for most of the services. This phase is particularly important in the case of retrofitting products already sold to the customer since it is necessary to understand if all of the products need connectivity.
b. *Commissioning and setting of relevant parameters*: If the installation and commissioning phase is completely delegated to the customer, wrong “parameter settings” can result in wrong information at the customer’s site.
c. *Installation and cloud connection*: As a starting point, the study declares that connectivity is one of the pillars to start the research, and devices are supposed to have this capability. Nonetheless, the service provider has to consider the fact that configuring all devices on one platform can be difficult, and the customer needs support to accomplish that successfully.
d. *Consultancy* can also be part of the service sub-system. Indeed, data analysis may need the support of an expert that interprets results and translates them into action to take. Some complex decisions cannot be automated yet, and the customer may do not have the necessary competences to clearly understand and interpret what to do with the results of data analysis.
e. *Implementation of suggestion*: data analytics lead to different decision making, that for a different level of services can be made from the customer itself or by the service provider directly, who has access to customer data. In case of the service provider performs actions, a structured back-end platform to monitoring the system at the customer site is required, and thus a process of service delivery.

v. ***Infrastructure***. In order to be able to develop and implement the final solution, specific infrastructure element need to be developed and implemented, that can vary from communication protocols, security standards, computing power, storage capability and so on.

After solutions have been defined, they can converge and be composed in order to create the ***final offer***. This final offer is the set of solutions that the service provider can release on the market in the form of a bundle. The composition of different solution can also be customised in accordance with the customer or directly by him, selecting on the platform the ones they prefer. Consider the totality of the solution requires to develop specifications for the product, service, infrastructure, software and data which all need to be interrelated.

In this study, the aspects related to the data domain have been investigated in depth. Indeed, the data sub-system represents the most innovative and least analysed in the context of service engineering, while product and software engineering are disciplines that have been shaped by several years of practice with different approaches (Ulrich and Eppinger, 2003; Águila, Palma, and Túnez, 2014).

Even though the data sub-system is further investigated in this thesis, all the dimensions are interrelated, and a specific data design may require considering the introduction of new characteristics of changes in the other dimensions. For example, if data needs to be retrieved from a sensor, it should be specified in the product sub-system, and if it should be linked with real-time notifications, the software part should be developed accordingly.

4.5.1. Data sub-system design

For what concerns the services based on the utilisation of data, the proposed methodologies focus on solutions delivered via platforms, in which different configurations of interfaces can be delivered with different accessibility to end-users at the customer site. It is possible to think about these kinds of service in a modular way, considering the possibility to use and reconfigure the same information differently and for different scopes and even include the possibility to add, replace, and update them.

In order to help the manufacturer in designing data-driven solutions, a specific data model has been proposed based on the ***Data Structured Systems Development*** **(DSSD),** also called the Warnier-Orr methodology. The method has evolved in the information domain analysis for representing information hierarchies using the three constructs for sequence, selection and repetition. The notations have demonstrated the suitability to model software structure since it could be directly derived from the data structure. Ken Orr (Orr 1981) has extended

Warnier's work to encompass a somewhat broader view of the information domain that has evolved into DSSD, which considers information flow and functional characteristics as well as data hierarchies. According to the brief characterisation presented, ***Warnier diagram*** (Warnier 1974) has been selected since it enables the analyst to represent information hierarchies compactly and transparently. Figure 42 reports an elementary example of the diagram structure. The information domain is analysed, and the hierarchical nature of the output is represented.

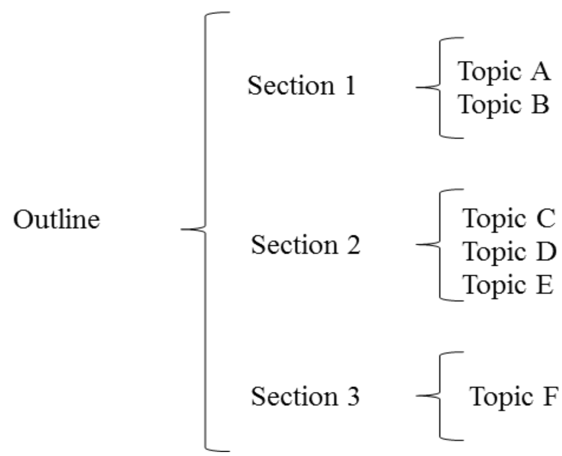


Figure 42 - Warnier diagram example

The different hierarchical levels have already been defined considering the development of specific DDPSS. Moreover, the proposed model aims to additionally consider other principles to fit the purpose, such as reusability, modularisation and the possibility of different configuration. Table 34 reports the different layers proposed for the construction of the data solution. Particularly, starting from the platform level, it defines each element of the hierarchy that enables the development of the solution. Different elements in a layer may converge in the one or more layer above.

Table 34 – DSSD for "Data" sub-system

Layer	**Description**
Platform	Represents the overall structure that is developed and deployed for a customer. It represents both the part of software and data into the product service "offer".

Layer	**Description**
	The platform represents the point of interaction of the client and should contain information needed to satisfy needs. The platform may have different user profiles to access, called interfaces, and different aggregation of information called dashboards, in which a set of predetermined widget and functionalities represent selected solutions
Dashboard	An interface represents a set of predetermined solutions that are dedicated to a univocal aim. Those solutions may be representative of descriptive, predictive and prescriptive functions.
Module	Data module of the solutions represents the composition of data analytics that together satisfy a user need. In this layer, the way analytics should be deployed to a customer has to be considered.
Data analytics	Data analytic layer is based on elementary analytics needed to compose a solution.
Feature	Features represent the first level of elaboration of data. It is essential since it defines aggregation policies. It is the basic package of information on with developing data analytics
Data	Data sources. It may include data gathered directly from the product, but also form different sources, that can be retrieved from external sources or from the customers. Some data may also be integrated by customer interaction with the platform. Raw pre-processed data

Based on the data structure, the service provider is guided in the definition of a customised solution, understanding how to compose functionality and information following the different levels. The table can be used with a top-down approach, if a solution has been already defined, as it should be considering all the previous steps but can also support bottom-up approaches, in the case where companies have specific data already available and then try to define some service to utilise it. Considering a top-down approach, it is possible to see that starting from a selected “data offer”, that can be defined as a dashboard, it is possible to define all of the visualisation and functionality needed. Then, from there, analytics and feature are defined until reach the layer where the single data and its source is determined. In defining data sub-system, and translate them into requirements, the designer has to take into consideration important customer requirements, for example: the frequency that is needed in collecting data, the right aggregation measures for the specific data, if only real-time data are needed or if data need to stored and so on.

4.6. Phase 6: Technical assessment

Technical assessment refers to the process that the DDPSS provider needs to perform to understand if it is possible to implement the solution. In this methodology, it is divided into two different sub-steps, *(i) resources identification, (ii) prototyping* and *validation*. Each step of the technical assessment has to be performed at a sub-system level and is divided into smaller packages. After a lower level test has been performed, it should be followed by an integration test at the upper level (that is represented by the solution) assure that all sub-systems coherently interact.

4.6.1. Resources identification

First of all, the service provider has to verify that all required resources to develop and deploy the solution are available or can be integrated to some extent. According to different parts of the solutions, three different resource groups emerge:*(i) developing resources; (ii) maintaining resources* and *the (iii) operations resources*. Indeed, there will be resources dedicated only to the development phase, but that the system should be maintained and upgrade recursively, and someone will be required to take care of all the back-end monitoring for problems related both to the technical malfunctioning but also service delivery. Those categories may include different typologies of resources such as human capital, time constraint, competences, economic resource, data resource and so on. Particularly, in the "developing resources" category, data resources should be identified, considering where data needed can be retrieved, both from the integration of new sensors or from external resources or partners. In the definition of the resources for one sub-system, more requirement for another sub-system may emerge. For example, considering the one of data, data storage technologies and spaces need to be defined, going to impact the infrastructure sub-system.

4.6.2. Prototyping & validation

After defining whether the required resources are available, prototyping and validation need to be performed. At this stage, technical steps that are performed from the service provider in order to create a first version of the solutions that should be compliant with the design and requirements are considered. Prototypes are realistic representations of the final solution that try to present to the customer how the solution will appear and works. They usually reflect the developer's interpretation of the user's needs, captured previously in either formal or informal communication. It is quite common that the communication results are distorted for various reasons and the prototype will frequently reveal how the misunderstanding will affect the final result (Gomaa 1987). With the validation phase, prototypes should be compared with all the requirements and technical functionality should be tested to prove that the platform and the system are functioning and performing as required. Prototyping and validation phases are recurring and can be repeated more than one times to achieve better results in terms of expectation and they can use different tools and techniques in different cycles.

4.7. Phase 7: Value assessment

The last phase refers to the customer's voice and profitability for the service provider. This has to be considered to ultimately confirm that the new solution has been implemented correctly and creates additional value. Moreover, network structures should also be considered regarding possible changes and the value created that it is possible to share with other actors.

4.7.1. Customer value assessment

The first step is the acceptance test for customers, such as testing that results meet the customer expectations and that the solution can be released for operational use. This is focused on the functionality of the system and is created ad-hoc for each different solution, formulating some acceptance criteria at the beginning and tested if they are satisfied. Besides functionality, another important dimension to include when introducing services and PSS is the assessment of the value that the solution delivers to a customer. Different studies proposed conceptualisation of the value perceived by a customer in the service context, particularly recurring dimensions have been reported in Table 35, on the review proposed by literature. (Plewa, Sweeney, and Michayluk, 2015; Gallarza; Arteaga, Del Chiappa, Gil-Saura, and Holbrook, 2017).

Table 35 - Service Value dimensions (adapted from Plewa, Sweeney, and Michayluk, 2015 and Gallarza, Arteaga, Del Chiappa, Gil-Saura, and Holbrook, 2017)

Study	Value dimension	
Presben and Xie (2017)	Knowledge value	Economic value
	Emotional value	Quality value
	Social value	Novelty value
Beneke and Carter (2015)	Perceived risk	Perceived quality
	Perceived relative quality	
Floh et al., (2014)	Functional value	Economic value
	Emotional value	Social value
Li et al., (2012)	Social/Emotional value	Economic value
	Utilitarian value	
Sánchez-Fernández et al. (2009)	Functional value (efficiency)	Quality
	Social value	Altruistic value
Maas and Graf (2008)	Company value	Social value
	Service/employee value	Product value
	Relationship value	
Sánchez et al. (2006)	Functional value of contact personnel	Emotional value
	personnel	Social value
	Functional value of service (quality)	
Pura (2005)	Monetary value	Emotional value
	Convenience value	Conditional value
	Social value	Epistemic value

Study	Value dimension	
Heinonen (2004)	Technical value Functional value	Spatial value Temporal value
Petrick (2002)	Behavioral price Monetary price Emotional response	Quality Reputation
Sweeney and Soutar (2001)	Emotional value Social value	Functional value of performance/ Quality Functional value of price/value for money
Ostrom and Iacobucci (1995)	Price utilities Quality utilities Friendliness utilities	Customisation utilities Experiment Service
Sheth et al. (1991)	Functional value Social value Emotional value	Epistemic value Conditional value
Zeithaml (1988)	Salient intrinsic attributes Extrinsic attributes Perceived quality	Other relevant high-level abstractions Monetary prices Non-monetary prices

For data application, specifically, initial considerations can be made on the value provided by the solution along the customer decision-making process. Elements that may represent value that a customer receives with a service that supports his decision-making process include:

- Automatic gathering of data;
- Translation of data into information;
- Lower levels of uncertainty related to that decision;
- Saving time to perform the decision;

- Risk-sharing with the service provider;
- Positive impact that the decision generates.

Nevertheless, the complete value assessment of complex and service-intensive offerings is often challenging to achieve. Ulaga and Reinartz, (2011) found that customer value assessment is specifically challenging for industrial firms providing hybrid offerings (i.e. combinations of products and services). Besides customer expectations when releasing the service, those kinds of applications needs to be also assessed from a value creation perspective, where value creation can be related to the customer sphere, to the provider sphere and the joint sphere between the two (Matschewsky, Lindahl, and Sakao 2018). Specifically, in the joint sphere, most of the value is created during the customer's usage over time (Möller and Törrönen, 2003; Grönroos and Voima, 2013) with respect to the outcomes realised by using them. Moreover, those services generate indirect benefits that are difficult to quantify and can be different for different customers.

4.7.2. Assessment of value along the value chain

Besides the value created for the customer, the solution should also be sustainable for the service provider who should consider not only the economic impacts but also contemplate other valuable effects that a solution may generate. Indeed some other benefits may be related to the customer lock-in effect that is generated from the solutions, from the image as a leading tech innovator, but also from network effects or the possibility to use same data with other utilisation for internal scopes, such as for the R&D department, the marketing, sales and so on.

In this view, data availability and DDPSS services need to be also assessed from a broader perspective, since different actors may benefit from them. Indeed, it has been recognised that those services should be approached with a holistic, multi-actor lens (Tronvoll 2017) considering the collaboration of interfirm and intra-firm actors (Sklyar et al., 2019). Thus, all actors that participate in the value creation process may contribute and benefit from the solution.

This step is proposed as necessary for the final assessment of the solution. However, a dedicated study should be performed as a further research topic, since it requires in-depth analyses.

A possible representation of the new network and new relationships is presented hereafter for exemplification purpose, to provide evidence of the actors that may emerge when considering DDPSS offering (Figure 43). In the representation, it is possible to see that ***new technology suppliers*** are included in the development of the solution, ranging from connectivity and cloud resources providers to data scientist and developers. Additionally, ***new competitors*** are depicted considering the fact that customer data may be related not only to the product itself, but also to the customer operation and more in general business, and other actors are already leveraging those data. Moreover, some other actors, defined in the representation as ***"3rd party"***, may have access to the platform data and deliver other kinds of services. Those actors are companies that should have either additional or complementary resources concerning the manufacturer, that can be e.g. data, competences or knowledge.

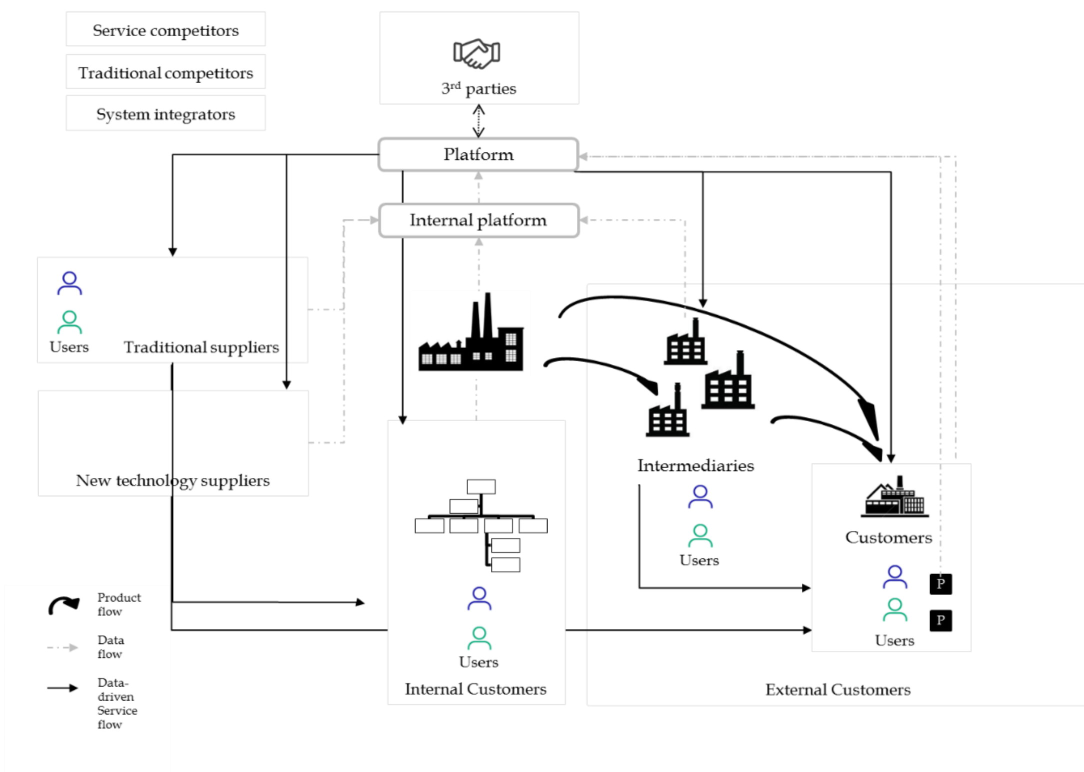


Figure 43 – Data-Driven Product-Service Network and Flow

Thanks to those relations and technological advancement, the service provider is now able to share information and offer them in the form of service, potentially addressing all the actors in the chain. DDPSS may be not only directed to the final customer but be designed for other actors, concerning their interest in data. Moreover, even though a service is designed for a specific actor, the same data, transformed into different information, can be used to create value for other actors. For example, an internal customer may gain benefit from customer applications: data analytics can efficiently support R&D to enhance the design and manufacturing of the product itself, may help the better definition of customer needs and segment supporting service engineering, marketing and sales department and so on. Traditional suppliers may understand potential improvement for their spare parts and better plan their production in accordance with the effective utilisation and state of health of products, and they can directly offer some new insight to the customer.

Moreover, considering the best possible scenario, another “internal platform” exists, where all actors directly interacting with the manufacturer along the chain, communicate performances data e.g. sales, and so on. The “product data platform” interact with the internal platform to gather information, and all those data can be used to offer services, potentially to all actors in the chain.

4.8. Continuous loop

At the end of Phase 7, if the hypothesized solutions do not create value for the customer or the service provider, the process can be repeated, closing the circular loop. Considering, instead, solutions that satisfy all the needs and requirements, the author suggests reanalysing the value chain established and select another actor in the chain to start the methodology cycle again. This actor can be both external and internal and, setting him as the customer for engineering a new service, the scope of the service should be settled in the different context but considering possible relation with the data that are now available for the customer. For example, some services can be defined for intermediaries, showing them aggregated information that is already gathered into the customer solution. For different actors identified, moreover, different users can leverage the same data in different ways, requiring the development of several solutions.

5. Application

The methodology has been applied into the ABB context until Phase5, to address the primary purposes of the presented thesis.

5.1. Phase 1&2: Service scope and customer need analysis

As shown in the DDPSS SE methodology description, the firsts two phases that will lead to the customers' needs definition are iterative and consist of:

a) The definition of the customer context in order to understand the service scope;
b) The "customer persona development" with respect to the service scopes that have been identified, in order to understand general customer needs.

Before performing the two steps, the "customer" in the ABB network has to be chosen. ABB is a company that usually sells products through different channels that are: wholesalers and distributors, system integrators, installer and panel builders. From intermediaries, the products are then sold to various customers, e.g., utilities; industries, transport infrastructures but also building of different size, from houses to hospitals. The focus has been placed on the ABB end-customer of CB products as a potential service consumer, which is the one that will most benefit from the adoption of connectable products, and from whom data arrive at ABB after the installation. ABB has a traditional market segmentation that gathers customers with respect to the applications of the customers. Nevertheless, in this methodology, ABB customers segmentation is not considered as it is, since the groups that are defined for products and system has not the same suitability for the DDPSS that have different features.

As a starting point, it has been decided to focus on a general industrial customer, in order to develop the ORM that will help the definition of possible service scope. As explained in the methodology, the map has been started considering (i) the product, i.e. in this case the CB has been positioned as the core of the customer context. Incrementally, the map evolved, adding relation to it. The main (ii) **activities** related to the product and what the product need has been added:

- CB are devices that should protect the electrical system from damages caused by short circuits and overloads. They result as a key element for enabling the energy to feed a system or to be interrupted;
- CB is a product that does not need intense supervision and requires standard maintenance ones or twice per year, with respect to the environmental condition like dust, temperature, end so on;
- CB needs to be chosen in accordance with different parameters and for specific CB typologies, some of them need to be set at the beginning of their lives. Moreover, the CB can be reset either manually or automatically after a fault, to resume normal operations;
- Every day they need visual control for voltage drop parameters;
- The expected life is quite long: it can last 20 years;
- Safety measures are fundamentals on the product since not safe interaction may result in a highly risky consequence for the operator;
- CB malfunctioning may have a significant impact on the customer side, both considering safety and economic losses.

Then the (iii) **system** in which they operate has been defined: Circuit breakers are fundamental means of the right energy flow in the electrical system. Moreover, they may indirectly impact the production since CB nonfunctioning may result in downtimes and they can also impact the living condition when feeding HVAC and illumination systems Subsequently, (iv) **decisions** that can in some way impact something directly or indirectly related to the product has been defined, that are for example the energy management strategies or the production schedule which also may affect the energy consumption as well as the renewable sources in which the company invest

Internal and external factors have also been mapped: into the energy domains, different (vii) **regulations** and certifications exist, like ISO 50001 and the LEED certificates. (v) **Rules** depend on the specific contract that the company may stipulate, and are directly connected with the customer country, and (vi) **contingencies** are here represented by the environmental conditions that may affect its functioning, like humidity, temperature and dust.

In the end, **(viii) roles** in the company have been added as potential users of the platform, that may be: maintenance operators, the maintenance manager, the facility manager, the production manager, the building designer, external consultant for energy reporting.

The model has been than redefined after the definition of the “persona” on which the company desired to focus since each of them has specific contextualisation that cannot be mapped a priori. In order to select the one to focus on, personas have been defined considering the three main possible service scopes that emerge into the initial ORM, that are the product, the energy system and the enterprise level.

Concerning **product scope**, personas can be divided into three main categories:

1. Large players with a significant percentage of the installed base from ABB. Those players are the ones that trust the manufacturing provider for their product quality and are interested in having good quality products and continuous availability;
2. Players with critical applications such as marine, nuclear power, which require a high level of safety. They represent a lower percentage but need specific service offering for what concern maintenance and product availability and correct functioning;
3. Small players. They have no direct contact with the manufacturer and usually use several brands in their plant. They are reluctant to sing maintenance contracts with the company and they usually rely on electricians to solve problems.

Concerning the **energy systems,** instead, customers should be divided into different categories:

1. Large industrial companies, which usually have internal systems to control flows, like SCADA or BMS. They have an energy manager and are interested in energy management practices;
2. Small and medium facilities. Their culture on energy management is low, usually, the figure of an energy manager is missing, and they rely on an external consultant for mandatory energy audits and certifications. Energy monitoring systems are not already present and they are price sensitive. Indeed they prefer to invest money in different projects with respect to the one of energy, which have more visible results;

3. Multisite commercial buildings. Their culture on energy management is increasing over the years, since one of their main expenditure is linked to energy consumption. They are interested in have monitoring tool and to the possibility to control more than one building at the same time, with a unique point of view. They may have BMS systems already installed.

Finally, for the **enterprise perspective,** customers can be divided into other categories:

1. Large players with an integrated IT system. Their interest is more into the extraction of data from the DDPSSprovider in order to merge it in factories platform.
2. Small players that do not have structured information systems are more interested in some solution provided by the customer in order to manage even business information.

According to ABB goals, it has been decided to focus on customers with medium-size facilities, that are used to perform maintenance with ABB partners and has no specific energy monitoring system. Moreover, it has been expressed that the main interest is into the energy system layer, i.e. the wish is to develop services that are related to the energy sector. As briefly mentioned before, those companies usually do not have a specific person devoted to the energy management initiatives, where investments in energy efficiency practices are low and energy consumption awareness is still “very poor or absent”, as also notice in the literature (May et al. 2017). Indeed the adoption of energy efficiency management in industries is still unexploited at its full potential, as defined in the so-called “energy efficiency gap” (K.-H. Lee 2015) Those industries have been selected since, in those contexts, low-cost sensing technologies and IoT paradigm are key to enhance energy efficiency practices. Advancement in new sensing methods, real-time analysis, connectivity, and the possibility to integrate new cyber technologies enable continuous monitoring of energy consumption and automatic evaluations of machine health and functioning, allowing efficient energy management (Edgar and Pistikopoulos 2018). Indeed, the availability of real-time energy consumption data creates optimisation opportunities: data analysis and mathematical models can enhance practices in production management.

When a specific "persona" is decided the ORM map need to be checked and updated considering its peculiarity. The detailed model is represented in Figure 44. For example, one interesting part that has been added consider the external energy consultancy company, which is usually called when needed. Scope of the services for those kinds of customers may be formulated with this general need: ***improve energy management and awareness and reduce energy cost***. They are immature on that point of view and they need support both to comply with energy standards, compute energy audit, check anomalous parameters, as it will be better explained in the next section.

Other personas can be of course developed, considering, for example, different applications. Indeed, it is possible to define as may persona as needed, considering different features and matching them.

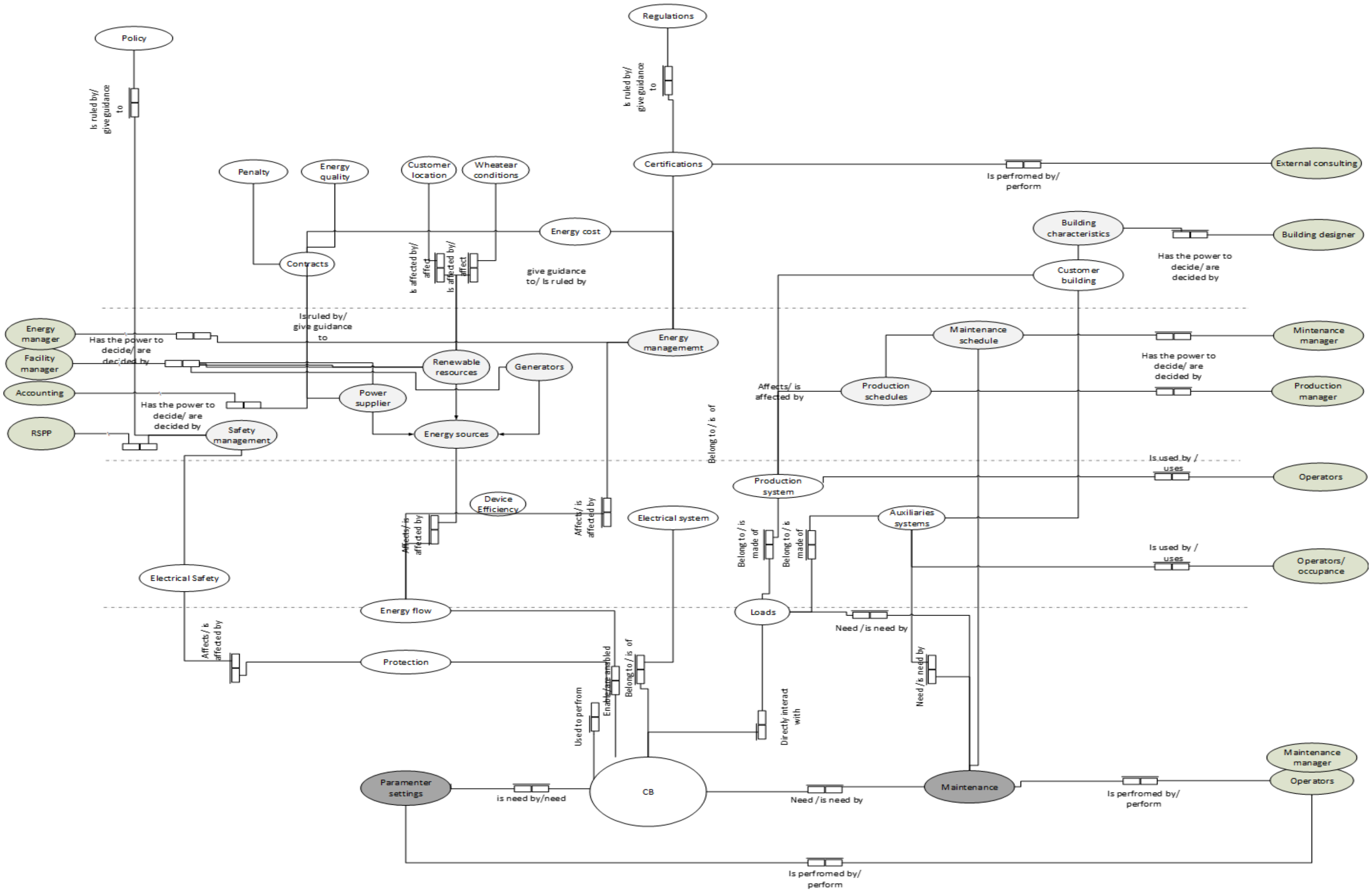


Figure 44_ Contextual model of an average industrial customer of ABB

5.2. Phase 3: Requirement analysis

After the definition of the leading service scope, customer segment on which to focus and its general need, potential platform users have been identified, to perform the second step, i.e. the requirement analysis. Specifically, those three roles have been pointed out:

- **Facility manager.** The Facility Manager is involved in both strategic planning and day-to-day operations and works closely with local business units. His/her responsibility covers more than one plant and should be interested in comparison among them, thus his/her interest in the platform can be related to the possibility to have all the facility connected in only one access point;
- **Maintenance manager.** Maintenance Manager will lead the factory maintenance team in the planning and implementation of initiatives that maintain and improve the reliability, effectiveness and/or efficiency of equipment, technical infrastructure, production lines and/or facilities. Develop and implement equipment lifecycle management procedures for optimising costs and profitability. His/her interest in the platform is supposed to be in the asset management and in the "predict" function, which monitors the health status of CB;
- **Energy manager.** He/she is in charge of all the energy monitoring and initiatives, which could be aimed at reducing energy cost, improve energy efficiency, and manage their carbon footprint.

For all of them, interviews had been performed following the job-to-be-done approach to take into account the duties they have with respect to the different areas. It has to be noticed that the energy manager is not internal to the company, and he oversees different activities also in sustainability and safety. He explains what he should have done considering having time, expressing his wishes.

The following table (Table 36) reports the main findings and considerations that emerged from the Job-to-be-done analysis, differentiating the level of impact that an action or a decision have (i.e. operational, tactical, strategical).

Table 36 – Customer journey/job to be done

Scope		***Electrical system: energy flow***
Operational layer	Maintenance operators	They have to know the ideal functioning ranges of CB and be sure the devices are operating in those conditions. Every day they perform more than one visual check on the panels (voltage drop parameter), and they check data connecting the physical device with a specific software directly with a cable. They take action in case of shutdowns, malfunctioning and so on.
	Facility manager	Check for inconsistencies and all problems that may be related or impact to infrastructures. They need to monitor that energy peak do not overcome the predefined thresholds; otherwise, they have to decide if to stop some specific load.
	Energy manager	They have to monitor and evaluate energy performance and energy data. They have to perform energy consumption and efficiency analysis, check energy consumption anomalies, look for trends, seasonality and correlation. In this case, the ISO 50001 certification is needed, energy audits have to be performed and in the near future, the installation of an energy monitoring system as required by Leg. Decree 102/14. In case of energy audit without a data collection system, a data collection session needs to be performed
Tactical layer	Maintenance operators	Decide to adopt new equipment and the retrofitting of some installation, their decisions can impact energy consumption. They collect all the faults that have been taken in place and they use a paper-based maintenance sheet. Then they use a portal to record all the historical data on the daily task performed. They used the portal to register also all the work orders and faults.

Scope		Electrical system: energy flow
	Facility manager	The only possible decisions he can make are related to corrective directions considering the industry facilities, i.e. invest in new equipment, renewable energy sources, infrastructural changes to increase the energy class of the building
	Energy manager	Make sure that the company comply with local directives. Check power consumption over the year Check energy expenditure and anomalies with respect to the predefined budget.
Strategic layer	Maintenance operators	They may plan energy efficiency-based maintenance
	Facility manager	Definition of investments towards better energy management
	Energy manager	They are in charge of monitor energy-saving strategies, define energy efficiency targets and EnPI.

Translating the defined solutions into system requirements can be a difficult task and the conceptualisation of a solution may require rethinking or redefinition of wishes. Therefore, the **cause-effect diagram** has been used to support the definition and development of solutions, in order to understand dynamics that need to be considered into the development of final solutions, for the ones that are not completely explicit. For example, different users know and highlighted the importance of penalties and unexpected energy expenditure, but they do not have a clear idea of what factors and how they impact energy costs. Given that, in order to understand how energy measures influence the economic parts, the following diagram has been elaborated considering all the peculiarity of the Italian energy contract that the Industry has. Specifically, only variable factors, on which a company has the power to act has been considered. As it is possible to notice in Figure 45 one interesting variable part is related to the power peak, which can be controlled by the company and that impact for a good percentage on the final energy bill, moreover also reactive energy is subject to penalties when overcoming a specific threshold. The reactive energy can also be measured considering the power factor (PF), which is the ratio of active and reactive power and should be as closer as possible to one.

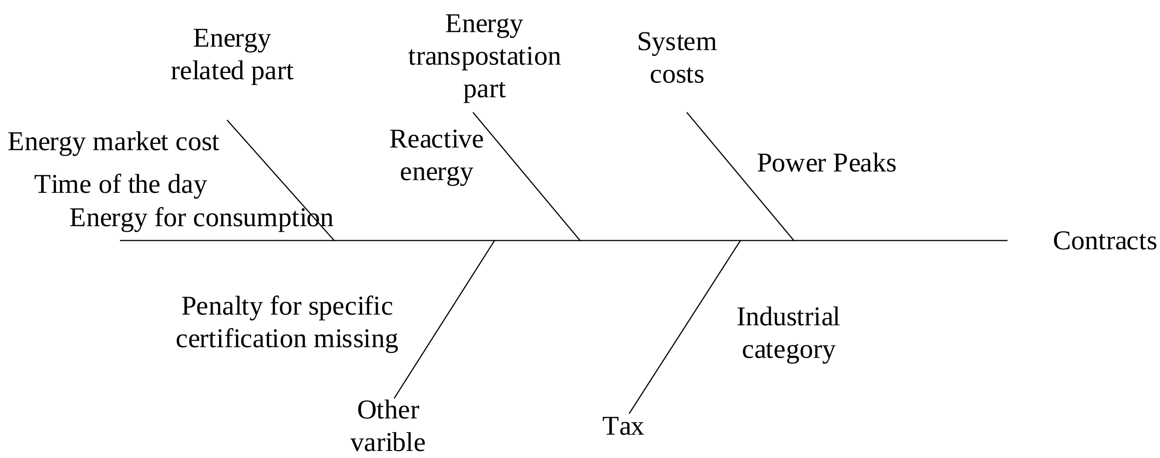


Figure 45 -Cause-effect diagram considering Italian contract of the selected company

Based on all the information gathered from the previously presented analysis, the Service Tree has been elaborated, as shown in Figure 46.

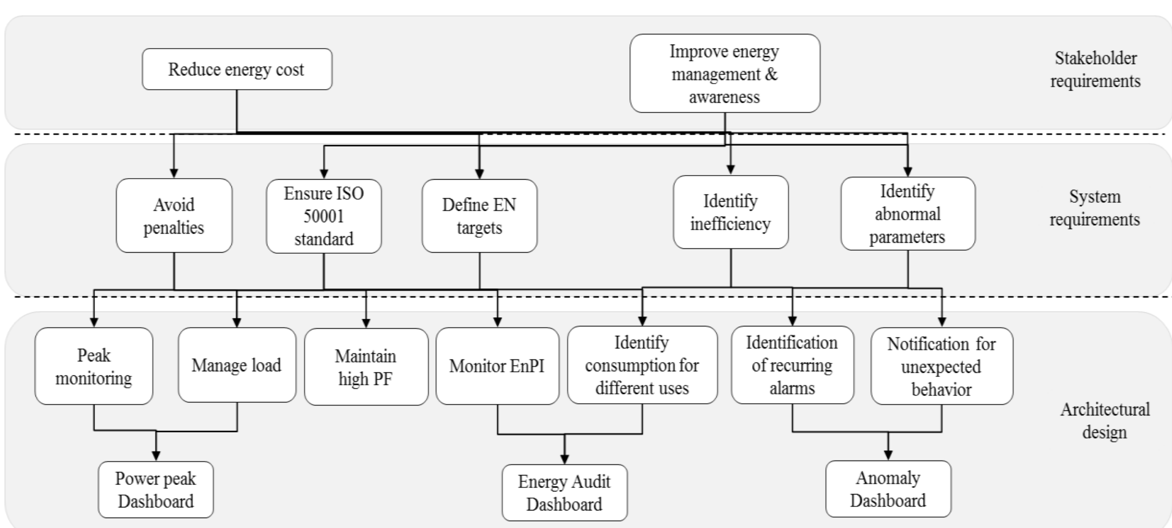


Figure 46 - Service Tree (Exemplification of the application)

Particularly, two main needs have been represented, which are (i) reduce energy cost and (2) improve energy management and awareness. Wishes have been defined for each of them, as reported in Table 37. As it is possible to see, some of the wishes aim to support the achievement of both needs. According to wishes and related analysis, the solutions listed in Table 37 have been identified.

Table 37- Relation between need, wishes and solutions

Need	Wishes	Solutions
(1)	Avoid penalties	Peak monitoring, manage load, maintain high PF
(1)(2)	Identify abnormal parameters	Peak monitoring, Notification for unexpected behaviour
(1)(2)	Identify inefficiency	Peak monitoring, Identification of recurring alarm
(2)	Ensure ISO 50001 standard	Monitor EnPI, Identify consumption for different uses
(2)	Define EN targets	Monitor EnPI, Identify consumption for different uses

The different solutions are gathered into three main possible homogeneous dashboards, that are (1) the “power peak”, (2) the “energy audit” and (3) the “anomaly” dashboard, that together satisfy customer needs, even not including PF, since it is already present in the platform.

5.3. Phase 4: Competitor analysis

An important step to be performed considering the development of the solution is the competitor analysis, looking at others success and failure on the market. Therefore, competitors analysis has also been performed, considering the solutions that other companies offer, in orders to understand if others have already implemented some offer that can be either successful or not. Specifically, not only traditional competitors, i.e. hardware producers have been taken into account since the scope of the service is into the Energy Efficiency Services (EES), that are services provided on a contractual basis that enable their customers to improve energy efficiency, using technologies and corrective actions to make the best use of available 'energy'. The EES market is growing considerably in the European context; it is estimated that from 2017, with a value of €26.7 billion, the market will grow by around 8% per year, reaching a value of €49.5 billion in 2025 ("Energy Efficiency Services in Europe Management Summary" 2019). This estimate demonstrates that energy efficiency services can be a key factor in the European industrial scenario and the main types of providers available on the market today are essentially six:

- **Automation Provider**: operators where the core business is data collection and they are developing ad hoc software for the optimal management of Big Data. For ABB global technology companies with core activities in electrification and automation represent the traditional competitors who usually offer hardware solutions, but their journey in the development of value-added energy services is still in its infancy;
- **Traditional ICT Provider**: they deal with data transmission and storage, trying to further develop the hardware and software part, with end-to-end solutions;
- **Utilities:** companies that deal with the sale of the energy carrier, but are increasingly encouraged to include energy efficiency services in their offerings;
- **Software House**: operators with the core business in data functionality, developing algorithms for the optimisation of energy assets and also focusing on data collection to develop products with integrated intelligence;
- **Energy Efficiency Operators**: are the incumbent operators who are interested in both hardware and software to keep up with the incumbents;
- **Startups:** entrepreneurial initiatives that are moving along the Digital Energy framework.

To perform the competitor analysis, 15 companies working in the EES sector have been selected, as reported in Table 38. Some of them, mostly the ones working in the automation field, represent ABB traditional competitors, while other players represent unconventional and smaller competitors, such as all the local companies offering energy data monitoring and analysis as the core business, which usually sell neither hardware neither complete solutions, but have more expertise on the energy domain.

Table 38 – Competitor list

Company	Typology
Aere	ESCo
Alienergia	Energy consulting
AlmavivA	Information and Communication Technology
Augury	Startup energy management
Bosch	Automation provider
DEXMA	E software provider
Domatica	Software provider
Enel X	Utility
Energy elephant	Startup energy management
Entronix	Startup energy management
Schneider	Automation provider
Siemens	Automation provider
Smartech	Energy
Zucchetti	Software house

In this competitor analysis, data-related energy services have been analysed, starting with essential services for companies that want to control their energy situation, to more advanced solutions, aimed at continuous improvement of energy efficiency. Particularity, attention has been posed on types of analytics that the competitor performed, that, according to the analytics taxonomy, can be distinguished in three different typologies, that are: descriptive, predictive, and prescriptive (G. Wang et al. 2016). Depending on those different approaches, data analytics techniques may impact to different extent the processes of knowledge creation and decision making. Particularly, predictive and prescriptive analytics play a vital role in helping companies make effective decisions on the strategic and operational direction of the organisation (Demirkan and Delen 2013). Specifically:

Descriptive analysis: It refers to historical or real-time data analysis yielding information on what happened or is currently happening for reporting and monitoring purpose. General tools adopted are traditional mathematics and statistics. Descriptive analytics also comprises more in-depth analysis aimed at understanding why things happened or are happening.

Predictive Analytics: It refers to the analysis of historical data to provide information on what will happen and why it may happen. General purposes detection of trend and relationships aimed at predicting future behaviour. Of course, it is not possible to guarantee the perfect accuracy of a forecast, but, through credit scores, it is possible to estimate possible events to prepare the organisation for future trends.

Prescriptive analysis: This is the most complex analysis and represents a new field in the world of big data. It allows the users to prescribe several actions and possible solutions to implement, guiding an activity. It relies heavily on advice, as it attempts to quantify the effect of future decisions to predict possible outcomes before they are adopted. It is not only a question of predicting future events but an explanation of the "whys" regarding such events and an attempt to find solutions for the various activities. They are still little used because of their administrative complexity, but, if developed properly, they can have big impacts in terms of decisions.

At the end of the analysis, seven service typologies emerged:

- ***Energy Audit***

  Energy audit is a systematic, documented and periodic assessment of energy efficiency. It is t a fundamental activity in energy management, as it allows to create a general view of the current situation, that is needed for subsequent analysis and corrective actions. It allows the definition, measurement and monitoring of KPIs. This type of activity also becomes essential when a company wants to certify its energy management system. It should be noted, however, that although all companies offer this service, some of them carry out the activity through an experienced consultant who takes care of installing sensors, collecting and analyse all the data. In contrast, other companies, once installed the devices, let carry out the related analysis to a specially implemented algorithm. An example of the latter solution is AlmavivA's SEM platform which, thanks to the intelligent algorithm they have developed, provides the audit autonomously and accurately, also providing a prescriptive analysis, or the prediction of future trends, with related improvement activities.

- ***Monitoring***

Most of the companies offer the possibility to monitor parameters and energy consumption continuously. Companies give the possibility to configure different interphases and visualise multiple information in different formats, e.g. chart types, tables, etc. Data are shown in real-time it is also possible to select different data granularity and visualise historical data. Monitoring function mainly refers to descriptive analytics and report to the customer what is happening and what happened. Few companies instead offer some predictive widgets; for example, the EcoStruxure platform is able to forecast the energy consumption for the next period. The companies rarely perform prescriptive analyses and the ones that indicated customer action to perform, are usually offering a consultancy service.

- ***Reports***

It is an activity that provides analytical documentation of the relevant energy information of the company within which it is implemented. The information must be as up-to-date, correct and objective as possible, so as not to be affected by any interpretative inconsistencies. What varies into the competitors offers is the frequency with which these reports are provided. Indeed, some companies offer a monthly report, such as Entronix, while others, like DEXMA, provide the report hourly, ensuring a constant update on the state of its production and energy system. Finally, some companies give the possibility to export a report in real-time, such as, SMARTech Ltd. that monitors the plant situation and energy consumption immediately, drawing up a report from on customer request.

- ***Alarms***

When reporting, the anomalies found in energy consumption should be recognised as quickly as possible. Some systems offer built-in alarm systems that notify them of such anomalies that will then need to be taken. Among the analysed actors, half of them gives the possibility to set thresholds, that if exceeded creates an automatic alarm so that corrective actions can be taken immediately. Schneider's EcoStruxure platform, for example, can provide a smart alert system that sends real-time notifications if there are some anomalies such as a power outage or unexpected energy spikes.

- ***Load management***

Another functionality that is offered by some players in the target market is the management of loads, that is, the ability to manage loads and utilities of production facilities and building, to avoid energy peak or under specific circumstances. For example, at a time when there is a peak in energy consumption, the system can, after being correctly set, recognise what is the reason for this overload and go to solve the situation by turning off a production component, such as an electric motor or a whole line. This is a complex task, since it is related to the daily production demand, because if the production system is saturated, it is not possible to do such operations, indeed most of the times, those system works manage non-critical loads, e.g. HVAC. The EcoStruxure platform, given an alarm about an anomaly of a given load the system, can turn it off or turn loads autonomously, and give the possibility to manage the same activity to an operator directly on-site or remotely.

- ***Certifications***

Some of the selected players offer their customers the opportunity to certify the requirements of their energy management system. The main certifications that are issued are related to the UNI CEI EN ISO 50001 standard, which sets the minimum requirements that an energy management system must have with a European-wide value. Other certifications that can be issued are TEEs (Energy Efficiency Titles), also known as white certificates, which certify the energy savings achieved by carrying out specific energy efficiency interventions. They provide an incentive to reduce consumption in relation to the distributed asset. Usually, those companies actively support their customers in the implementation of an ISO 50001 certified energy management system and also releases the negotiable TEEs once the desired energy savings have been achieved. In order to do that, some data analytics feature is also employed, such as give the possibility to customers to record energy savings with the platform and continuously monitor EnPI.

- ***Consultancy for energy efficiency improvements***

The last services concern all the activities related to consultancy to help customer to improve energy management end reduce energy costs.

Considering the analysed companies, ESCos are the ones that perform those activities as their core business, accompanying the customer towards energy efficiency. Nevertheless, some players offer their client the software and strategic support alongside an EGE expert who deals with energy improvement. An example of this type of company is Domatica, a software house that sells its platform to the customer to work on, but also offers a consulting service through an expert in energy management.

As it is also possible to see from competitor's offers, the solutions proposed in the Service Tree are in line with the functionality and services already sold in the market. Indeed, competitors are mainly focused on ISO standard and energy audits. The analysis of power peak is also considered and fulfilled with alarms and load management. Moreover, analysing the offers, it is possible to notice how experts mostly provide prescriptive analytics and energy improvement suggestions as consultancy service. While monitoring, report alarm and audit are also deployed though platform, as also the ABB decided to do.

5.4. Phase 5. PSS Design

Design phase consists of the definition of the final offer, which needs to consider all the different parts that it includes, i.e. the product, the data, the software, the service and the infrastructure. In accordance with the prementioned needs and wishes, the data module for the solution is hereafter developed. Specifically, "power peak" and the "energy audit" dashboards have been considered.

5.4.1. Data Module

The data modules have been defined with the support of an **expert of the domain**, i.e. a consultancy company in the energy sector.

Starting from the power peak dashboard, the support of the expert enables to understand that the amount of energy cost related to the power is calculated based on the highest monthly peak that occurs for a duration longer than 15 minutes. Given that, if even one peak occurs during the month, the power quota for the whole month is calculated on that peak. For example, from an analysis of the historical data, it is possible to notice that in October 2019 and November 2019 there were two sporadic but significant peaks (238%, 263% compared to the average) that significantly affected the overall cost. The energy expert also helped into the clarification that there is no penalty related to the exceeding of the contractual energy, but the utility uses the number of exceeding that threshold only to change and propose different contracts. This strongly influences system requirement since the solution should not consider static thresholds but more elaborated analysis that computes the highest peak during the month, that last more than 15 minutes. The data module has been defined as represented in Figure 47, considering the implementation of the following important features:

- Monitor real-time peak variation and send alert to help customers to act before 15 minutes are exceeded;
- Continuous monitoring of the maximum and values during time;
- Identification of the load that cause the highest peaks;
- Evaluation of benefit related to the investigation of problems considering the potential savings of the month;
- Check consistency between the bill and the values reported in EDCS.

Load management has not considered in the data module, since the company has already a working software that performs the activity.

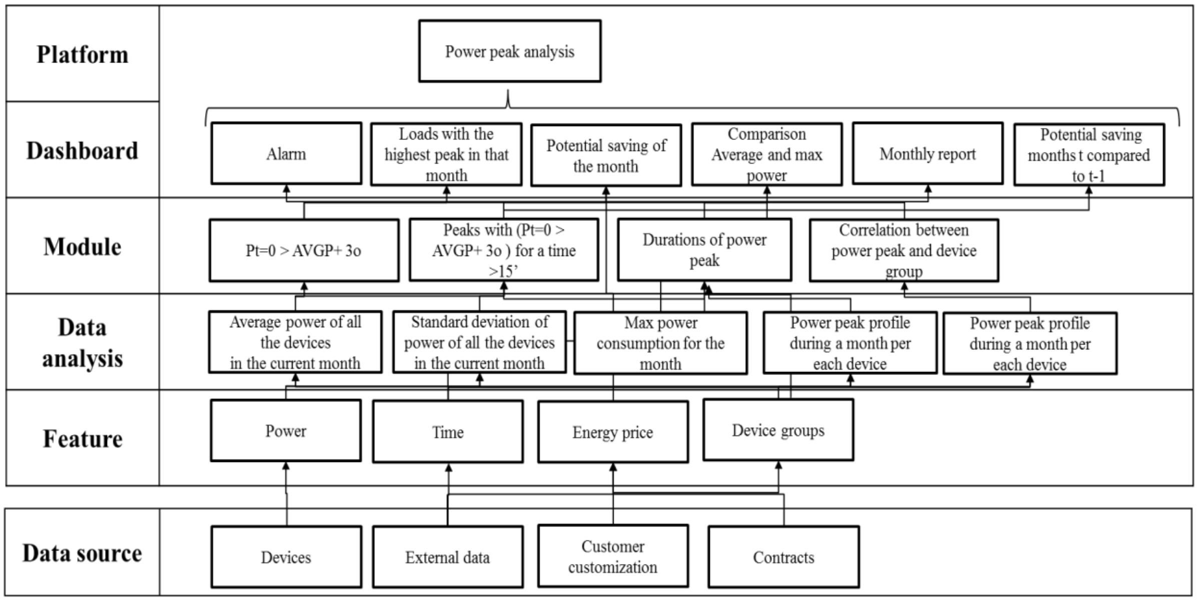


Figure 47 – "Power peak" data module

Another analysis that has been performed with the support of an energy expert regards the Energy audit requirements. A team of EGE, suggested important feature to be implemented, that are:

- Aggregation of the energy expenditure considering the following groups:
  - Functional areas;
  - Process and auxiliary utilities;
  - Utilities related to a specific department.
- Possibilities to create a hierarchy of the individual devices in the group;
- Development of EnPIs for productivity and emissions;
- Comparison of measurements for different periods;
- Computation of energy costs.

The data module has been defined as represented in Figure 48. As it is possible to see, energy audit dashboard requires less analytics to be computed, since not specific rules, need to be applied. Nevertheless, it requires a higher number of data sources, since the features are for example related to the CO2 emissions, that is a parameter that the device does not gather, but that is defined into the ISO 50001, from specific conversions table that needs to be included automatically, or should be inserted manually from the customers, developing a dedicated setting page.

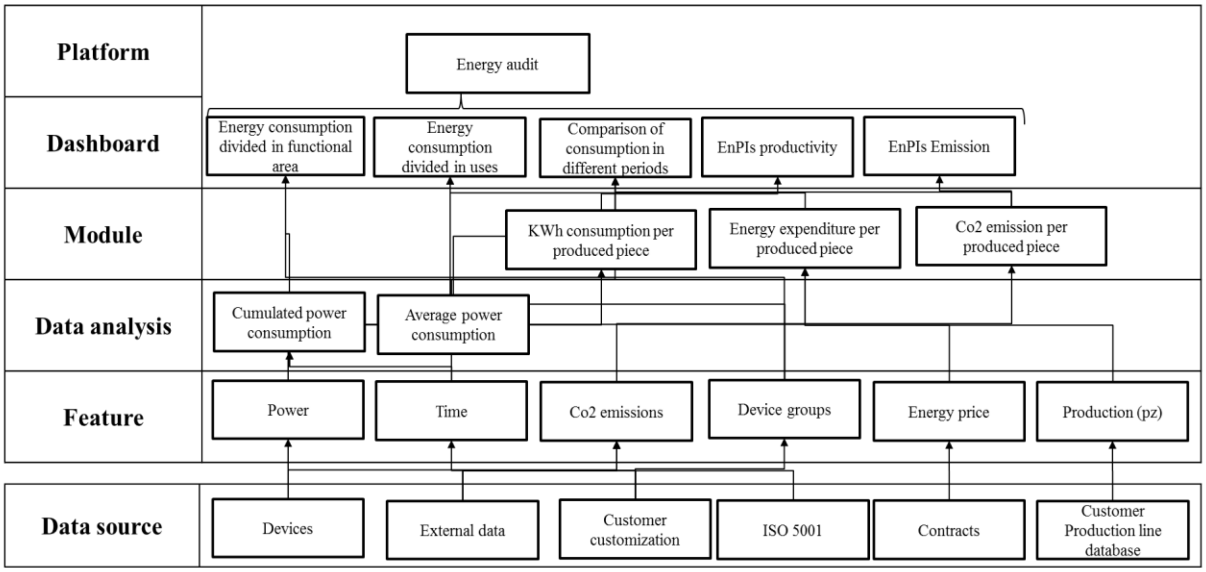


Figure 48 – "Energy audit" data module

The different suggestions have been proposed to the development team Specifically, the Energy audit dashboard has been implemented and deployed into the platform, while the power peak has been remaining the pipeline with a lower priority. Figure 49 shows some implemented widgets into the energy audit dashboard and Figure 50 and Figure 51, represent mock-ups for the possible future implementation of the power peak dashboard.

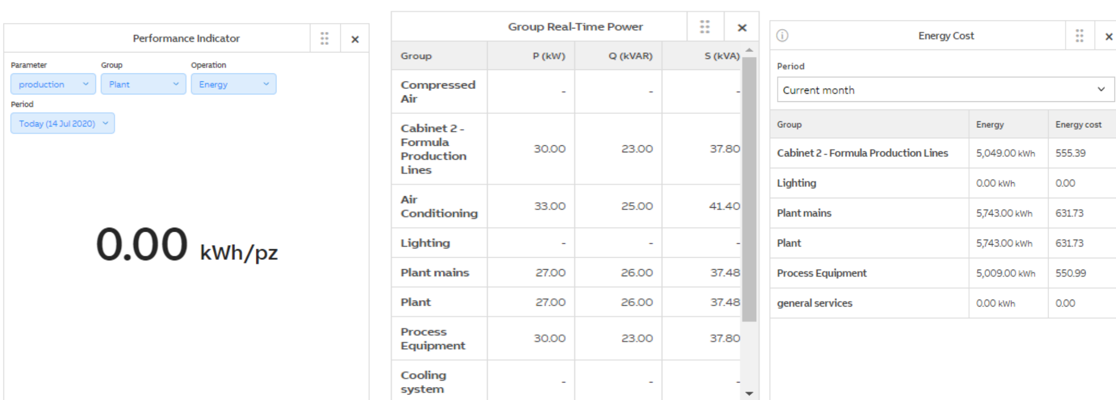


Figure 49 – Example of widgets implemented into the Energy audit dashboard

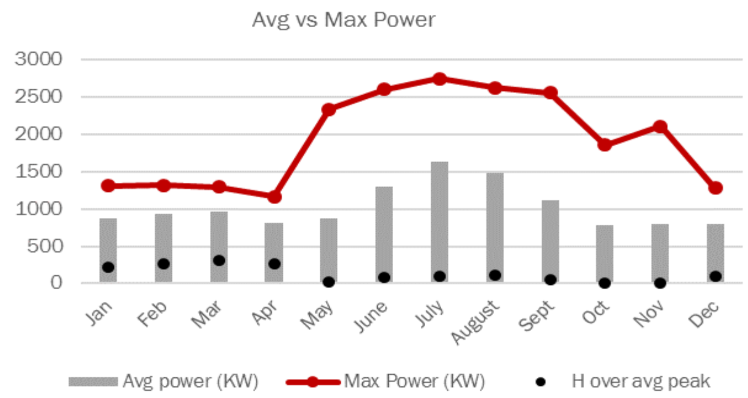


Figure 50 – Example of comparison between Average power and Maximum power

	Avg power (KW)	Max Power (KW)	Potential Saving	Cumulated	H over avg peak
Jan	875	1312 €	1.905,76 €	1.905,76	217
Feb	936	1320 €	1.672,61 €	3.578,38	272
Mar	967	1296 €	1.432,97 €	5.011,34	304
Apr	806	1168 €	1.579,59 €	6.590,93	264
May	872	2336 €	6.381,22 €	12.972,15	15
June	1300	2600 €	5.665,00 €	18.637,15	89
July	1628	2752 €	4.139,76 €	22.776,91	95
August	1482	2624 €	4.205,77 €	26.982,67	115
Sept	1118	2560 €	5.313,22 €	32.295,89	46
Oct	780	1856 €	3.965,01 €	36.260,90	1
Nov	803	2112 €	4.822,69 €	41.083,59	2
Dec	805	1280 €	1.749,96 €	42.833,56	104

Figure 51 – Example of the report on the potential savings

6. Validation

The methodology has been validated involving potential users, i.e. ABB employees that usually participate in the definition of new service offering, both considering people dealing with strategies, development, definition of value proposition and company portfolio. Particularly, since the service and the digital teams are still separate entities into the company, people from both have been asked to contribute to the validation. Five people have been involved that hold the following job positions:

- Head of Energy Management and Digital Solutions

  He/she is responsible for the definition of the strategies for digital products, connectivity infrastructure, and digital solutions related to energy management. He is in charge of collecting customer needs and sales feedbacks in order to define value-added solutions.
- Digital leader

  He/she is responsible for the development and management of all digital offers that will add value to the customer experience, through all their life cycle phases, according to market needs and internal strategies and targets.
- Head of Global Service Management

  He/she is accountable for driving the service portfolio strategy (including customer value proposition definition and Market price positioning) and the portfolio development (to drive profitable growth by meeting customer requirements, anticipating market trends and ensuring design competitiveness with a suitable service offering.
- Head of Global Service Product Manager

  He/she is accountable for the long term profitable growth and marketing of the ABB Service Product offering to targeted market segments, by developing and managing it through all of its life cycle phases, according to market needs and internal strategy and targets.
- Global Service Product Manager

  He/she is responsible for the definition of the service portfolio, both hardware and digital service solutions. He is in charge of collecting customer needs and sales feedbacks in order to define the digital offering that will add value to the customer experience.

They participated in a dedicate workshop in which the methodology has been explained both from the theoretical point of view and by means of examples and the support of the application into ABB context. The participants have been asked to fill a form, in which different questions have been designed in order to validate the clarity, the completeness, the consistency and the usability of the proposes methodology. Moreover, specific questions have been designed to investigate if effectively fit with the ABB reality, both in terms of the need to focus on the specific point and if it is interoperable with the already existing approaches. Appendix C reports the validation form. As it is possible to notice, it is organized in two main sections: the first one dedicated to the different phases and methods, and the second one to the overall structure. In the first one, for each of the methodology phases and methods proposed, different statements have been proposed to the respondent. In a similar way, another set of statements has been defined for the second section. In addition, some open questions have been formulated.

The following part will show the average score of the respondent, that used a scale from one to five to evaluate the different statements where five means that they strongly agree with the statement and one that they totally disagree with it. Moreover, an interrater agreement index has been calculated to compute the agreement between different respondents (Smith-Crowe et al. 2014). Particularly, the researcher computed the r_{WG} index, which is a comparison between the observed variance in ratings and the variance of a null distribution (i.e., a theoretically specified distribution representing no agreement). The agreement, then, is evaluated demonstrating that the variance of the collected ratings is sufficiently less than the variance that would be expected without agreement. The closer the r_{WG} value to 1, the greater is the agreement between respondents**.**

Specifically, r_{WG} for a single statement has been calculated as follows:

$$r_{WG(j)} = 1 - (\frac{s^2}{\sigma^2}) \qquad (1)$$

where s^2 is the observed variance in ratings of item j and σ^2 is the variance of the null distribution. Considering σ^2, researchers usually define the null distribution as the uniform, or rectangular distribution, where each response category is equally likely, thus, the variance has been calculated as:

$$\sigma_u^2 = (\frac{A^2 - 1}{12}) \qquad (2)$$

where A is the number of response per each statement. The use of the uniform distribution as the null distribution assumes that no response bias is present

Table 39 shows the evaluation of statements referred to the different phases of the methodology that has been extensively discussed, i.e. from Phase 1 to Phase 5. It is possible to notice that the phase that is less understood is the first one, which represents an innovative development with respect to traditional methodologies. Indeed, the need to identify new service scope and the customer context is linked to the expansion of service boundaries as a consequence of the possibility to gather customer data and enter his reality. When considering the execution of phases in the ABB context, the scores are on average lower with respect to all the other evaluations, demonstrating confidence in the way they approach the development of new solutions. Nevertheless, it is interesting that disagreement emerges, since different respondents demonstrated their different perception of the activities that are already executed. For example, all of them agree on the fact that the competitor analysis is an important phase; nevertheless, some of them are satisfied with the actual degree of analysis in ABB, while for others it should be conduct deeply.

Table 39 – Evaluation of the phases not extensively defined into the DDPSS SE Methodology (from Phase 1 to Phase 5)

	Clarity		Consistency		Clarity		Usefulness	
	The goal of the phase is clear		The phase effectively supports the development of PSS solutions (i.e. the phase is needed)		The output of the phase is clear		The phase, nowadays, is not extensively executed/contemplated into ABB approach	
	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$
Phase 1	4,8	0,92	4,2	0,52	3,8	0,72	3	0,75
Phase 2	5	1	5	1	4,6	0,68	3,6	0,87
Phase 3	4,6	0,88	4,8	0,92	4,8	0,92	3,8	0,62
Phase 4	5	1	4,2	0,72	4,8	0,92	2,6	0,65
Phase 5	4,8	0,92	4,4	0,88	4,2	0,72	3,4	0,87

Table 40 reports the evaluation of statements referred to the methods and tools that have been proposed to perform and achieve the scope of the different phases. As it is possible to notice, even without negative feedback, the most difficult tool to be understood is the Contextual Conceptual model followed by the DSSD. Despite this, it seems clear how the method can support the achievement of the phase goal and it is clearly stated that no other tools are contemplated into the ABB approach to reach the same goal. Some other concerns come also for the usability of other tools such as the Service Tree and the cause-effect diagram. This evaluation can be reconducted to the fact that they did not try to use the different tools directly, and they need to perform an application case before assessing their usability. Moreover, a complete agreement has been revealed concerning the necessity of the support of an expert in the domain of the service scope, for which an additional open question has been asked, revealing the lack of competences in areas that are not the traditional focus of the company.

Table 40 – Evaluation of proposed methods and tools

	Clarity		**Usability**		**Usability**		**Consistency**		**Completeness**	
	I am able to understand how the method “works”		I am able to understand how the method can be applied/ implemented		The method is easy to use		The method effectively supports the attainment of the goal of the related phase		The method is enough to reach the goal of the related phase	
	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$	$\bar{X}$	$r_{WG(1)}$
Contextual Conceptual Model	4,4	0,88	3,2	0,52	3,6	0,88	4,4	0,72	4	0,6
Persona development	5	1	4,6	0,88	4,2	0,92	4,8	0,92	4,8	0,92
Job-to-be-done	4,8	0,92	4,6	0,88	4,6	0,88	4,6	0,92	4,8	0,92
Service Tree	5	1	4,6	0,88	3,8	0,92	4,6	0,88	4,6	0,88

	Clarity		Usability		Usability		Consistency		Completeness	
	I am able to understand how the method "works"		I am able to understand how the method can be applied/ implemented		The method is easy to use		The method effectively supports the attainment of the goal of the related phase		The method is enough to reach the goal of the related phase	
	$\overline{X}$	$r_{WG(1)}$	$\overline{X}$	$r_{WG(1)}$	$\overline{X}$	$r_{WG(1)}$	$\overline{X}$	$r_{WG(1)}$	$\overline{X}$	$r_{WG(1)}$
Cause-effect diagram	4,6	0,68	4	0,8	3,6	0,68	4,4	0,88	4,4	0,68
Data Structured System Development	4,4	0,68	3,8	0,92	3,8	0,92	4	1	3,8	0,92

Table 41 and Table 42 report the evaluation of statements referred to Phase 6 and Phase 7, for which slightly different questions have been proposed, since no methods are defined for the methodology for different reasons. Phase 6 is considered to be the less innovative phase, since technical feasibly and prototype are extensively addressed both from the literature and from ABB that uses a well-structured agile software development approach (DevOps), and different platform environments for test feature and production. Indeed, it is possible to see their positive agreement on the understanding of phase applicability and implementation even without the proposal of supportive tools. The same agreement is also present for the consideration of the phase into the ABB approach.

Phase 7, on the contrary, needs a deeper and dedicated investigation both considering the theoretical point of view and also into the industrial domain, which is usually oriented to purely economic evaluation metrics such as the ROI. Two separated questions have been proposed on the need to verify the value that the customer and the actor belonging to the network may benefit from DDPSS solutions. Furthermore, in both cases, the ratings were positive, and participants agreed with each other. It is as well-validated the fact that the phase is not extensively executed into their usual approach, as it is possible to see from the high rating of the last statement.

Table 41 – Evaluation of phases 6

	Statement	Score	
		$\overline{X}$	$r_{WG(1)}$
Clarity	The goal of the phase is clear	5	1
Consistency	The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	4,6	0,88
Clarity	The output of the phase is clear	4,6	0,88
Usefulness	The phase, nowadays, is extensively executed/contemplated into ABB approach	4,6	0,88
Usability	I am able to understand how the phase can be applied/ implemented	4,4	0,88

Table 42 – Evaluation of phases 7

	Statement	Score	
		$\overline{X}$	$r_{WG(1)}$
Clarity	The goal of the phase is clear	4,6	0,88
Consistency	The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	4,4	0,88
Consistency	There is the need to verify the value that the customer benefits from the solutions	4,2	0,92
Consistency	There is the need to verify the value that all the actors belonging to the network may benefit from the solutions	4,2	0,92
Clarity	The output of the phase is clear	4,4	0,88
Usefulness	The phase, nowadays, is not extensively executed/contemplated into ABB approach	4,6	0,88

Table 43 reports the evaluation of statements referred to the overall methodology. As it is possible to notice, the average score is overall high and also the agreement between respondents is always over 0,8. They evaluated particularly positive the fact that the methodology considers all the different steps needed to reach a valuable DDPSS offer, following a logical path. While the most critical point regards the usability of the methodology for which the participants clearly stated their need to use it before evaluating. Particularly the service team has been less confident in showing a high positive score for the specific statements. This difficulty in evaluating the usability can be also related to the fact that they did not participate in the presented application.

Table 43 – Evaluation of the overall methodology

	Statement	Score	
		$\overline{X}$	$r_{WG(1)}$
Clarity	I understand the complete procedure of employing the methodology	4,8	0,92
Clarity/Usability	I understand how to apply the methodology in a real workplace	3,4	0,88
Completeness	The methodology covers all the steps needed to understand customer needs and translate them into a PSS solution	4,6	0,88
Consistency	The methodology follows a logic order compatible with my reasoning process	4,8	0,92
Usability	The methodology is easy to use	3,4	0,88
Consistency	The degree of effort/work required by the methodology is coherent with the final output	4,4	0,88
Completeness	Every information needed to develop the services is considered in the methodology	4,4	0,88
Interoperability	The proposed methodology may interoperate with established ABB tools and methodologies (i.e. the DevOps approach, already performed customer segmentation, competitor analysis, ACE sessions)	4,2	0,92

Overall, the results of the validation session demonstrated that the methodology had been appreciated as a supportive tool into the development of DDPSS, and from all evaluations, it is possible to derive the following findings:

- ***Clarity***: The methodology resulted clear for all of the participants. All phases and methods have been understood by all the participants during the presentation, even though some of them showed preferences for exemplifications rather than theoretical concepts;
- ***Completeness:*** All necessary phases have been included in accordance with the participants' evaluations. Indeed, a high ranking of completeness criteria have been expressed by the group;

- ***Consistency:*** The different phases and methods have also been evaluated considering their effective support to achieve the final goal. The group shows consensus towards the different phases, the logical path they follow and the necessity of all steps into the realization of the DDPSS solution;
- ***Usability:*** The ease of use of the methodology represents the lower scores. Indeed, most of the participants explicitly declared their concern to evaluate the usability without going in deep with a specific application in their domain. The participants that answered with positive scores are the ones that also followed the pilots project and the application that has been presented during the workshop. Nevertheless, the scores are not negative, representing the difficulty in evaluating the different statements;
- ***Usefulness:*** The methodology is perceived as helpful by all the participants; indeed, they showed a strong option towards the general benefit of using the tool. Moreover, apart from the competitor analysis and the feasibility assessment, it emerges how all the other phases are not extensively executed in ABB's traditional approach. This indicates that the general approach of the tool was accepted and appreciated within the group of participants;
- ***Interoperability:*** The adoption of the methodology does not represent obstruction with the preexisting ABB activities. None of the participants showed particular issue into the interoperability of the presented methods with the ABB tools and methodology.

7. RQ2 Outcomes

This chapter aims to answer RQ2:

> ***RQ2: How is it possible for a manufacturing firm to move from data acquisition, enabled by the integration of sensors with products and by connectivity, to DDPSS offerings?***

The presented chapter proposed a Service Engineering methodology for the development of DDPSS, based on the SEEM that is designed for traditional PSS. It considers new aspects to be included with respect to the characteristics of DDPSS, and resulted into seven phases, which are (1) definition of service scope, (2) customer need analysis, (3) requirement analysis, (4) competitor analysis, (5) PSS design, (6) technical assessment and (7) value assessment. For each of the phases, different tools and methods have also been proposed, based on the necessity raised from the literature review and the industrial requirements. The methodology addresses the RQ2 proposing a structured process and related methods that support the development of DDPSS.

The actualization of the methodology has been demonstrated through a comprehensive application into the ABB context based on previously harvested information and works performed along all the Ph.D. period. A validation session has also been performed with ABB employees that hold positions that participate in the definition of new services and solutions, both traditional and digital-based. The validation demonstrated positive feedback from practitioners on the methodology, both considering its applicability and usefulness.

The methodology emphasizes the active role of the customers into the definition of the solution and also in the validation phase, integrating it with the PSP point of view, also considering internal resources and feasibility of the solution. It complies with modularity and reusability principles, going to support agile and flexible development of the solution, without replication of needed data into a single database and is also in line with customization principles that enable the offering to be composed according to the specified user and information he needs to visualize. It also takes into consideration the need for all the other aspect of the offers that are richer than the information visualization tool. Indeed, it highlights how the solution should also consider the product, the service delivered in its traditional meaning, the software and the infrastructure sub-systems.

The most innovative parts of the methodology are represented by Phase 1 and 5. In phase 1 the necessity to explore the customer context and understand possible service scopes that are not concerned with the traditional product-orientation of the company are considered. In Phase 5 the "Data subsystem" is deeply explored, and the application of the DSSD is proposed to support the development of DDPSS solution. On the contrary, the other sub-systems have been addressed partially, mainly due to the fact that it is the less explored sub-system, while for the product, software and service development well-established method exist. Phase 7 can be also considered an innovative perspective, since it introduced the value dimension and assessment as essential aspects to be considered. Nevertheless, this dimension should be further investigated. Future work developments should focus on the value-chain dimension, and the assessment of the value created from the service for all actors. Moreover, challenges regarding data ownerships, visibility, information sharing along with the network and the participation of different actors in the DDPSS provision should also be discussed.

Phase 6 is considered to be already extensively covered into ABB approach, and consequently, the need to develop supportive tool has not risen; however, other companies may have the different necessity and require the definition of methods and tools also for this phase. This emphasises the fact that multiple case study may also be performed, to reach a higher level of generalization of the methodology applicability.

Some other limitations should also be highlighted; indeed, the presented methodology does not consider the utilization of data analytics techniques to better profile customers and their behaviour and preferences, such as customer feedback loop, platform utilization or open-source data that may also be considered into the definition and enhancement of service offering. It also does not take into consideration the willingness of a customer to pay for a specific service, even if the customer value assessment should also end with an indicator of the perceived value for the customer from an economic perspective.

VII. CONCLUSION

Digital solutions and communication technologies transform the daily life of people and companies "as fundamental as that caused by the industrial revolution" (European Commission 2020). Industry 4.0 and digital servitization represents two of the most impacted field from digital solutions, that may benefit from it and generate profit. However, with the rise of digital technologies, a wide spectrum of challenges regarding both infrastructures and people has to be addressed, reaching from wireless network and computing capabilities, to data ownership and security. One of the key themes for research and development is the also value that can be generated in the servitization domain from data availability. In accordance, this dissertation work started considering the interrelation between Industry 4.0 data-related technologies and servitization transformation of firms. A first analysis has been carried out to define the main gaps and the subsequent objective of the presented thesis. Particularly, it has been highlighted how the two trends under analysis maintain separate knowledge and research stream, indeed, as also emphasised by Frank at al., (2019), the connections between Servitization and Industry 4.0 is still emerging (Alejandro G. Frank et al., 2019). There are some tentative of overlapping, but they maintain most of the time the two concepts disconnected; indeed, most of the studies do not consider the manufacturing perspective, or, when the technological part is deeply analysed, the servitization perspective is weekly addressed. From the literature review emerged the need for a systematic understanding and synthesis of the possibilities that technologies and data availability open in the service field. There is a lack of the overall comprehension of data-related services, that not only concern their characteristics but the overall development process. (Parida et al., 2019; Tronvoll et al., 2020; Anke, 2019).

The literature review has been accompanied by an in-depth analysis of industrial requirements where similar needs have been observed; indeed companies are struggling to develop new solutions and usually handle them with traditional approaches, lacking an initial comprehension of what the DDPSS is and may offer.

Given the prementioned analysis, which is extensively explained in chapter II and chapter III, the two gaps mentioned above have been selected as the main research scope. Accordingly, the following research questions have been formulated:

RQ1: Which are the characteristics and specific features of DDPSS that differentiate them from the traditional PSS

RQ2: How is it possible for a manufacturing firm to move from data acquisition, enabled by the integration of sensors with products and by connectivity, to DDPSS offerings?

In this view, two different results have been proposed in the presented thesis, that are:

- A conceptual framework that depicts DDPSS typologies, synthesizing key characteristics that they have. The development of the framework has been based on existing literature in combination with the results of multiple case study research, validating the characteristics derived from literature, using a theory-building approach;
- A DDPSS SE methodology that has been designed to support the development of a successful solution. Starting from a recognized SE methodology for the traditional PSS development, the researcher integrated key aspects of DD domain, and proposed changes and supplement to fulfil new needs, in accordance with both the literature analysis and industrial requirements.

The contributions of the two artefacts are oriented both to theory and practice; indeed, the research project has been developed considering a continuous interaction between the theoretical domain and the practitioner point of view, achieved with an intense literature analysis and an action research project that lasted all the duration of the PhD path. Moreover, this thesis relies on the interaction with other practitioners, all involved, even at different stages, into the path towards digital and data-driven servitization, aiming at providing general results.

1. Contribution to theory

This thesis contributes to the literature base in the field of servitization, specifically the sub-stream of digital servitization and data-driven PSS. It also considers filling the gap that emerges clearly between the technological perspective and the servitization perspective, providing tools and methodologies aiming at synergistically address both domains. Specifically, the two different artefacts, provide the following theoretical contributions:

- Focusing on the characteristics of DDPSS, a holistic understanding of DDPSS typologies and possibilities for manufacturing companies has been developed in the form of a two hierarchical framework. The framework creates synthesis and homogeneity on the definition of DDPSS and their key components;
- The DDPSS SE methodology provides a new unique approach to the development DDPSS focusing on the SE of the data related part. The methodology differentiated from the other into the actual state of the art including relevant innovations that are related to the peculiarity of the DDPSS domain, that are the (i) enlargement of service scope, (ii) data availability, (iii) software-based solutions, (iv) reusability principles and (v) value chain perspective.

2. Contribution to practice

This thesis was motivated by problems and challenges that impact managerial practice. Key motivation were the difficulties of traditionally product-oriented manufacturing firm to embrace the path towards digital and data-driven servitization and the lack of knowledge into the data domain. The thesis has been developed in collaboration with an industrial company and the support of other several companies into a service management community, investigating their problems and providing tools that are able to support them.

The research proposed two artefacts that also resulted in actionable tools from manufacturers:

- the DDPSS framework is a starting point to support the DDPSS development since it has been demonstrated that help practitioners to hypothesize possible future development in order to enlarge the service portfolio creating a TO-BE state on the framework. The applicability of the framework and the willingness to use it have been demonstrated in the application case.

- The DDPSS SE methodology, instead, provides a set of methods, principles, and rules to guide the development of DDPSS, whit a specific focus on service and data module. Starting from the collection of stakeholder needs, to the definition of specific solutions and their requirements for the development phase, the methodology also includes the validation and assessment both related to the service provider and the customer and the overall value chain.

  A validation with practitioners shows that the general approach of the tool was accepted and appreciated within the group of participants.

3. Limitation and further development

This thesis presented two artefacts that aim at contributing to the general understanding and development of DDPSS, considering the gaps and challenges that emerged from the literature and industrial requirements. As a general remark, the thesis is oriented on the DDPSS concept, strongly focusing on the service part that is provided and delivered on account of the primary source data gathered by the product and sensors at customer locations, while it does not extensively consider the implication on the hardware part, i.e. the product. Additionally, the research started with a high level investigation of two general concepts, that further research could address from different perspectives and deepening into specific aspects considering for example the availability of customer-generated data, or the utilization of innovative data analytics techniques to exploit data potential.

Besides the boundary of the research, several limitations are also inherent to both of the artefacts and can be considered as a starting point for future development and improvements.

Considering the DDPSS framework, it has to notice that, even it gives the possibility to start thinking of possible new development, it is not a prescriptive tool; indeed, it is not related to the definition of managerial strategies to reach different service offering. Specifically, it takes into consideration neither technologies nor business models, which are two key factors in the determination of the feasibility of solutions. In fact, the technological decision may limit the possibility to explore some of the levels of the presented offer, and on the other side, the same technologies may enable manufacturers to introduce innovative business models. Moreover, a further evolution of the tool may tack in the direction of the definition of a maturity model concerning the typology of services that are mapped into the framework.

Considering the SE methodology, instead, the first main limitation is the fact that has been applied and validated in a single, even rich, context, i.e. ABB company. Supplementary industrial cases would add value and rigorousness to the presented findings; nevertheless, they require high commitment to be completed. Secondly, not all phases have been entirely discussed. Indeed, even it is emphasised that the development of all the sub-system need to interact, Phase 5 is explored proposing a tool for the design of the "data sub-system", mainly because it is the less explored sub-system, while for the product, software and service development well-established methods already exist. Phase 6 is considered to be well covered in the company, while it may be better explored for other ones. Finally, Phase 7 need to be deeply addressed, considering the structures of the value chain and value assessment into the context of DDPSS offering.

The fact that the adoption of data-driven technologies is reshaping the network structure, including new actors in the value chain and new value co-creation and collaboration practices, has been highlighted not only in this phase but also during literature analysis. It is clear that there is the need to understand how ecosystems are structured and characterized in a DDPSS context, how value co-creation and collaboration practices change in relation to the ecosystem structure and how data and information should be shared in order to create value. Nevertheless, the topic is slightly included in the presented research, remaining an interesting open future development. This embraces the understanding of networks with dynamic value creation along the lifecycle as well as value creation models and data valuation. Furthermore, value creation architectures for digital and service platforms (Ngo and O'Cass 2010) are the main development need. Companies show confidence and invest resources to support their servitization approaches with platform-centred architectures (Alejandro Germán Frank, Dalenogare, and Ayala 2019), using a multitude of technologies and layers (structural tiers of the architecture) to complement their specific infrastructure and business needs (Cenamor, Rönnberg Sjödin, and Parida 2017). Another interesting dynamic to be further analysed in this direction is also the possibility to include different 3rd parties into the participation of the DDPSS offering, since it is the less explored potential of DDPSS characteristics, as defined in Chapter V. In this view, platform openness impact can be studied since is among the decisions that go to impact the ecosystem configuration and enable different value creation mechanisms, both to the end-users, the platform and to the application developers (Menon, Kärkkäinen, and Wuest 2020).

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Appendix A

Complete and numbered list of papers constituting the corpus of papers of the Systematic Literature Review described in chapter II.

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Appendix B

Interview protocol

Areas of investigation	Objective(s)	Guiding questions
Contextualization of the path through the connection of products, utilisation of data gathered, and the types of services offered using data collected	Understanding the "digital path" of the company and having a precise overview of the service they offer using data and their evolution.	1.Can you tell us about the "digital path" of your company? 2. How many products on-field are connected? 3. What are the product-service offers based on data? How have they evolved over time? 4. Which are the decisions that the service supports/enables both for your company and for the customers? 5. Are services delivered automatically of needs customer feedback?
Data collection	Understand what types of data are collected according to their "proximity to the product" and for what purpose.	1.Which data do you collect from the product? 2. Are they related to customer operations? 3. Do you need to integrate data from other sources? Which ones? 4. The services offered to what/who are for? 5. How "close" are the services offered to the product?
Storage and visibility of the data	Understand which data sharing mechanisms are in place between customers, service providers, and eventually other actors.	1. How are the data stored? 2. Do you have visibility on customer data? If no, why? If yes, which kind of data are shared with you? 3. With whom are the data shared? 4. Do you share data with other partners in your ecosystem? 5. Do you share the data with external service providers?

Areas of investigation	Objective(s)	Guiding questions
Data processing	Define how the service provider handles data processing.	1. Who analyses the data? 2. Which kind of approach do they use? 3. Do you have a structured organization responsible for data analytics? 4. Which are the analyses that you need to perform? 5. Is human interpretation necessary to extract information from data? 6. Which analytics are available to the company?
Use of data	Understand how data and data analytics are translated into applications and services.	1. Which is the utilisation of data gathered? 2. Where data are processes? 3. Did you implement a dedicated visualization tool for customers and your organization? 4. Who decides the action to implement considering data analysis? 5. Who owns the responsibility for the decisions? 6. Is the product able to “answer” to some changes? 7. Which analytics are available to the company and the customers?
Openness of the deployment system and cooperation with service providers	Receiving information about the possibilities of importing/exporting data from the system and the possibility of processing/developing applications or providing services for other parties.	1. Is it possible to import/export data from the customer platform? 2. How can you or other actors access data? 3. Partners have the same access to data? 4. Is it possible to develop applications on the platform for a third-party supplier? 5. Who is responsible for service delivery?

Appendix C

Validation form "Data-Driven PSS engineering"

Job position of the respondent ________________

Section1: Evaluation of phases and related methods

Define your agreement with the following statements, using a scale from 1 to 5, where 5 means that you strongly agree with the statement and 1 you totally disagree with it.

Phase 1 - Definition of service scope

Evaluation of the overall phase

Statement	Score
The goal of the phase is clear	
The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	
The phase, nowadays, is not extensively executed/contemplated into ABB approach	

Evaluation of the proposed method: Contextual Conceptual Model

Statement	Score
I am able to understand how the method "works"	
I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	

The method is enough to reach the goal of the related phase	

Do you think that the presented method could be substituted with other methods that you know and/or you already work with?

Phase 2 - Customer needs analysis

Evaluation of the overall phase

Statement	**Score**
The goal of the phase is clear	
The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	
The phase, nowadays, is not extensively executed/contemplated into ABB approach	

Evaluation of the proposed method: Persona development

Statement	**Score**
I am able to understand how the method “works”	
I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	
The method is enough to reach the goal of the related phase	

Evaluation of the proposed method: Job-to-be-done

Statement	**Score**
I am able to understand how the method “works”	

I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	
The method is enough to reach the goal of the related phase	

Do you think that the presented method could be substituted with other methods that you know and/or you already work with?

Phase 3 – Requirement analysis

Evaluation of the overall phase

Statement	Score
The goal of the phase is clear	
The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	
The phase, nowadays, is not extensively executed/contemplated into ABB approach	

Evaluation of the proposed method: Service Tree

Statement	Score
I am able to understand how the method "works"	
I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	
The method is enough to reach the goal of the related phase	

Evaluation of the proposed method: Cause-effect diagram

Statement	Score
I am able to understand how the method "works"	
I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	
The method is enough to reach the goal of the related phase	

Do you think that the presented method could be substituted with other methods that you know and/or you already work with?

Phase 4: Competitor analysis

Evaluation of the overall phase

Statement	Score
The goal of the phase is clear	
The phase effectively support the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	
The phase, nowadays, is extensively executed/contemplated into ABB approach	
I am able to understand how the phase can be applied/implemented	

Phase 5: PSS design

Evaluation of the overall phase

Statement	Score
The goal of the phase is clear	

The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	
The phase, nowadays, is not extensively executed/contemplated into ABB approach	

Evaluation of the proposed method: Data Structured System Development

Statement	**Score**
I am able to understand how the method "works"	
I am able to understand how the method can be applied/ implemented	
The method is easy to use	
The method effectively supports the attainment of the goal of the related phase	
The method is enough to reach the goal of the related phase	

Do you think that the presented method could be substituted with other methods that you know and/or you already work with?

The methodology suggests also the involvement of an ***expert in the domain,*** considering all the service scope that are not concerned with the traditional ABB know-how. Do you think that his/her involvement is necessary?

Phase 6 Assessment for feasibility

Evaluation of the overall phase

Statement	**Score**
The goal of the phase is clear	
The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
The output of the phase is clear	

The phase, nowadays, is extensively executed/contemplated into ABB approach

I am able to understand how the phase can be applied/ implemented

Phase 7 Solution evaluation (future development)

Evaluation of the overall phase

Statement	Score
The goal of the phase is clear	
The phase effectively supports the development of PSS solutions (i.e. the phase is needed)	
There is the need to verify the value that the customer benefits from the solutions	
There is the need to verify the value that all the actors belonging to the network may benefit from the solution	
The output of the phase is clear	
The phase, nowadays, is not extensively executed/contemplated into ABB approach	

Section2: Evaluation of the overall structure

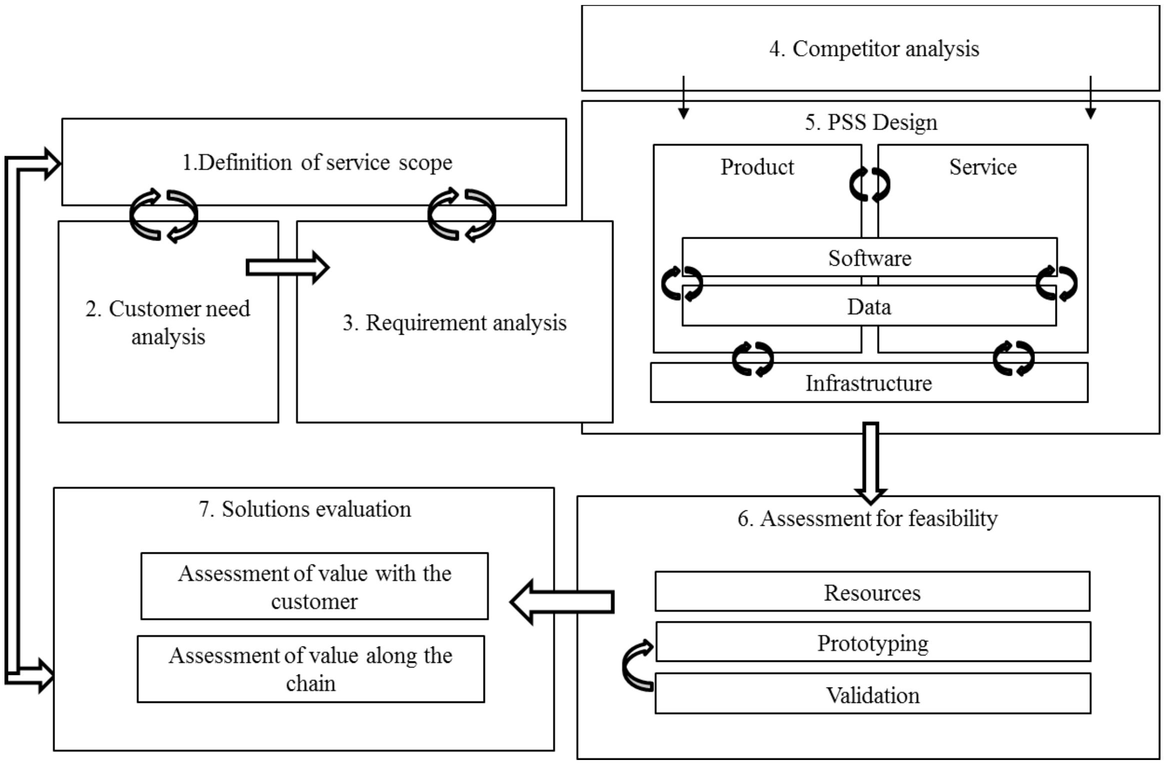

Figure 1– DDDSE Methodology

Define your agreement with the following statements, using a scale from 1 to 5, where 5 means that you strongly agree with the statement and 1 you totally disagree with it.

If your evaluation is from 1 to 3, can you please provide a brief comment for possible improvements/suggestions?

	Questions	Score	Comments
1	I understand the complete procedure of employing the methodology		
2	I understand how to apply the methodology in a real workplace		

	Questions	Score	Comments
3	The methodology covers all the steps needed to understand customer needs and translate them into a PSS solution		
4	The methodology follows a logic order compatible with my reasoning process		
5	The methodology is easy to use		
6	The degree of effort/work required by the methodology is coherent with the final output		
7	Every information needed to develop the services is considered in the methodology		
8	The proposed methodology may interoperate with established ABB tools and methodologies (i.e. the DevOps approach, already performed customer segmentation, competitor analysis, ACE sessions)		

In your opinion, what are the main strengths and drawbacks of the methodology?