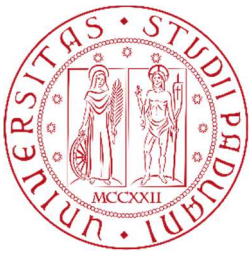
Università degli Studi di Padova



Department of Economics and Management

Master Program in Entrepreneurship and Innovation

Advanced digital services in Italian manufacturing firms: technologies, skills, and ecosystems

Supervisor **Marco Paiola**

Candidate **Kineret Rumer**

ID Number 1231614

Academic Year 2021/2022

APPENDICE

Dichiarazione di autenticità

Dichiaro di aver preso visione del "Regolamento antiplagio" approvato dal Consiglio del Dipartimento di Scienze Economiche e Aziendali e, consapevole delle conseguenze derivanti da dichiarazioni mendaci, dichiaro che il presente lavoro non è già stato sottoposto, in tutto o in parte, per il conseguimento di un titolo accademico in altre Università italiane o straniere. Dichiaro inoltre che tutte le fonti utilizzate per la realizzazione del presente lavoro, inclusi i materiali digitali, sono state correttamente citate nel corpo del testo e nella sezione 'Riferimenti bibliografici'.

I hereby declare that I have read and understood the "Anti-plagiarism rules and regulations" approved by the Council of the Department of Economics and Management and I am aware of the consequences of making false statements. I declare that this piece of work has not been previously submitted – either fully or partially – for fulfilling the requirements of an academic degree, whether in Italy or abroad. Furthermore, I declare that the references used for this work – including the digital materials – have been appropriately cited and acknowledged in the text and in the section 'References'.

Firma (signature)

Kineret Riemer

Summary

Introduction 1
1. The challenges of modern industries 4
1.1. Background in Industry 4.0. 5
1.2. Background of servitization 8
1.3. Convergence of Servitization and Industry 4.0. 11
2. Set of technologies 14
2.1. IoT 14
2.2. Cloud 15
2.3. Data Analysis and Big Data 18
2.4. Artificial Intelligence (AI) and Machine Learning (ML) 19
2.5. Additive Manufacturing 20
2.6. Augmented Reality 22
3. Service business model innovation (SBMI) 24
3.1. Internal and external factors in servitization 24
3.2. SBMI and product-service systems BMI 27
3.3. Impact of external relationships in SBMI 30
4. Empirical Research 34
4.1. Survey methodology 35
4.2. Descriptive Analysis 37
4.3. Qualitative Comparative Analysis (QCA) 52
4.3.1. Methodology, purpose, and other applications 52
4.3.2. Set conditions of the csQCA 55
4.3.3. Results 62
4.3.4 Analyzing cases 66
4.4. Discussion 71
Conclusions and implications 78
Bibliography 85
Annex 90
Survey questions: Italian 90
Survey questions: translated in English 95

FIGURES

Figure 1. Theoretical framework of Industry 4.0. technologies. Source: Frank et al. (2019)..... 5
Figure 2. Smart Manufacturing and Smart products technologies. Source: Frank et al. (2018)..... 6
Figure 3. Table of technologies for Smart Supply Chain and Smart working. Source: Frank et. al (2018) 7
Figure 4. Classification scheme of industrial Services of hybrid offerings. Source: Ulaga et al. (2011) 10
Figure 5. Innovation trajectories for Industry 4.0. and Servitization. Source: Frank et al. (2019) .. 11
Figure 6. Conceptual framework for Servitization and I4.0. Source: Frank et. al (2019) 12
Figure 7. Cloud architecture. Source: Xue & Xin (2016) 16
Figure 8. Table of Big data origin and target use. Source: Smarti et al. (2014) 18
Figure 9. AI's components. Source: Canhoto and Clear (2020) 20
Figure 10. Classification of process categories, technologies and materials. Source: ASTM (2012) 21
Figure 11. Theoretical framework for servitization process. Source: Dmitrijeva et al. (2020) 25
Figure 12. Impact on value creation, value offer and value capture of different conditions. Source: Muller et al. (2018) 29
Figure 13. Dimension of the firm of the respondent 38
Figure 14. representation of responses of the ranking of a push towards the project..... 40
Figure 15. Distribution of respnses about the use of a certain technology in the PSS project 42
Figure 16. Ranking of the respondents of the level of customization of their services 43
Figure 17. Distribution of responses about the usage of the technologies inside of the firm 44
Figure 18. Distribution of responses about the impact on different value..... 45
Figure 19. Response about the utilization of technologies inside the firm..... 46
Figure 20. Distribution of the ranking of the respondent about friction in the project by different areas..... 47
Figure 21 Graphs of results of average number of previously mentioned relationships (top-left), given importance to characteristics of this relationships (top-right), position in the supply chain (bottom-left) 49
Figure 23.The importance attributed by the respondents to product, software, services, and communication 50
Figure 24. Distribution of ranking by the respondents about the future of the firm..... 51
Figure 25. Representation of necessary and sufficient conditions. Source: Thomas and Brunton (2014) 62
Figure 26. Truth table obtained in the fsQCA 3.0. software 64
Figure 27. Truth table obtained by the analysis 64
Figure 28. Set of conditions and their definitions in the software..... 65
Figure 29. Graph summary of the result of the QCA 74

TABLES

Table 1. Internal and External dimensions of the impact in servitization. Source: Dmitrijieva et al. (2020) 24
Table 2. Role of the respondents involved in the survey..... 35
Table 3. The answer of the respondents about the sector of business. 37
Table 4. Duration of the PSS project of the respondents..... 39
Table 5. The answer of the respondents about the current stage of the PSS project. 39
Table 6. Distribution of answers about the presence or absence of a key client 41
Table 7. Responses about perceived importance of service in the strategy..... 41
Table 8. Responses about perceived digital readiness in the company 42
Table 9. Distribution of responses about the type of offered service 43
Table 10. Distribution of responses about the relationship with the final user..... 44
Table 11. Responses about perceived participation of internal competencies in the project..... 46

Table 12. Responses about perceived response in the project 47
Table 13. Details about new external relationships 48
Table 14. Summary of the conditions chosen for the QCA 56
Table 15. Thresholds for the presence or absence of each condition. 60
Table 16. Analysis of necessary conditions 63
Table 17. Results of the standard analaysis in QCA 65
Table 18. Summary of the ID of respondents divided by path 66
Table 19. Summary of assumptions, conditions and ID of respondents 72
Table 20. Details about external relationships 77

Introduction

This work proposes to give an overlook of the most recently developed technologies available for the manufacturing firms with a focus on the PSS (Product Service System) project implemented by some Italian Manufacturing companies. In addition, the aim is to better understand which are the paths that can explain a business model innovation in the servitization process.

This work is divided into four chapters.

The first Chapter proposes to introduce some fundamental concepts in the field. A first part concentrates on the definition and description of Industry 4.0. while the second part focuses on servitization. In the last part of the chapter a union between these two topics is presented. The result is an overall look into the literature to better understand the theoretical background. The aim is to link two concepts that too often are treated separately but that co-live inside the firm.

In Chapter 2 a more in-deep analysis of the set of technologies comprehended in the survey is proposed. The definitions of some important advanced technologies are reported. The second part of the chapter analyzes which internal and external factors can influence the servitization process of a firm. This part will be also fundamental to developing the empirical research in the following part. More in detail, it is necessary to understand the conditions specified in the developed model.

Continuing, Chapter 3 presents a literature review of the concept of business model innovation in digitalization and servitization. In the first part the internal and external factors in servitization are described and detailed. The aim is to analyze business model innovation in the product-service system project of manufacturing companies. The purpose of the last two parts is to present an overview of the service BMI and explain how it can be enabled by the creation of new external relationships as networks, collaborations, and partnerships.

The fourth and crucial Chapter analyzes the survey administrated to a sample of manufacturing Italian firms in collaboration with the Digital Lab of the University of Padua.

The aim of the investigation is to understand if the presence of some conditions has a true impact on the business model innovation of those firms accordingly with the literature. More specifically the goal is to understand which conditions can lead to a major intensity of new external relationships and how this combination of variables can change accordingly with the size of the firm.

In the first part of this Chapter, methodologies, purposes, and other applications are reported as well as the survey methodology. Later, two different analyses are developed.

The first one is a descriptive analysis in which are presented all the answers obtained by the involved sample. While, in the second part, a Qualitative Comparative Analyses is developed. More specifically a set of Boolean variables are defined to carry out a crisp set QCA. The aim is to test some specifical academic assumptions and to investigate the paths that may lead to a BMI. The result will be then reported and discussed in the conclusive part of this study. Implications, limitations and possibilities for further analysis are also developed in this final chapter.

1. The challenges of modern industries

In the past decade, two recent macrophenomena and trends are specifically challenging the business models (BMs) of productive firms: servitization and industry 4.0. Servitization mainly concentrates on adding profit to the customer (demand-attract) while Industry 4.0 happen frequently has a connection with the accumulation of value to the production process (technology-push) (Frank, Mendes, et al., 2019a).

Starting from the servitization process we can affirm that many firms are transitioning from designing, creating, and selling products to innovating, selling, and delivering services to solidify their position in competitive markets (Ulaga et al., 2011). In addition, the servitization strategy of productive companies consists of a transformation journey of product-centered firms towards product-service systems or the so-called PSS (Kowalkowski et al., 2017).

This will be an important topic in the development of this work. In fact, the PSS refers to the output of the servitization process, in other words, it represents a set of integrated products and services able to provide functionalities to the customers and stakeholders. (Frank, Mendes, et al., 2019b). Accordingly, Ulaga et al. (2008) analyzed the domain in which in the business scenario there is an hybrid offering.

As previously mentioned, the other important component of modern manufacturing firms is Industry 4.0. I4.0. is considered as a new industrial scenario in which servitization shifts is developing. In fact, the convergence of different emerging technologies, strengthened by the Internet of things (IoT), results in cyber-physical and intelligent systems that can create value for industrial activities (Frank, Dalenogare, et al., 2019). Many academic scholars insist on the fact that this kind of technological innovation also is the key to a radical business model innovation (Müller et al., 2018).

Major of existent studies link Servitization only to Digital Transformation not analyzing the connection with Industry 4.0. Indeed, others analyze the value creation using IoT solutions in Servitization (Rymaszewska et al., 2017).
In addition, some literatures have considered only the contribution of specific tools for servitization: remote monitoring (Grubic, 2014), cloud computing (Wen and Zhou, 2016), or big data (Opresnik and Taisch,2015). Further research concentrates their efforts on the business view of the Digital Transformation in Servitization: classification of digital PSS

and integration between Servitization and other business dimensions often considering the need for a re-design of operational process to achieve it (Frank, Dalenogare, et al., 2019). Generally, these studies tend to emphasize the importance of technologies in contributing a service value delivery to the customer. Anyway, it does not imply a direct connection between Industry 4.0 and Servitization. In fact, basing the research only on technologies such as IoT, cloud, big data, and analytics is not sufficient to create a convergence between servitization and Industry 4.0 (Frank et al., 2019).

Only a recent stream of research followed this purpose, working on the connection between Servitization and Industry 4.0. For instance, Frank et al. (2019) have taken into consideration digital platforms for service offering in their Industry 4.0 framework trying to fill this connection gap and embracing Servitization as a part of Industry 4.0. To fully understand the theory developed in their research a further introduction about Industry 4.0. and Servitization is needed.

1.1. Background in Industry 4.0.

The term Industry 4.0. was coined by a German in 2011 thanks to a collaboration between the government, universities, and private companies (Frank, Dalenogare, et al., 2019).

In manufacturing systems, it can be seen as a new industrial step in which a range of emerging and convergent technologies create value for the entire product lifecycle (Wang et al., 2016). The technologies embodied into I4.0. can be split into two different groups as shown in *Figure 1* .

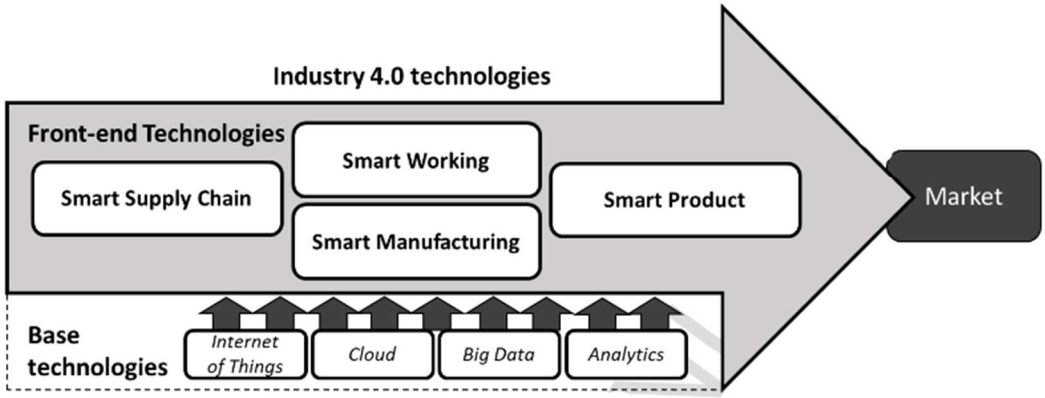


Figure 1. Theoretical framework of Industry 4.0. technologies. Source: Frank et al. (2019)

In the middle, we have "*Front-end technologies",* called so because their dimensions are linked with operational and market requirements. That considers the development of manufacturing activities based on *smart manufacturing* and how they are offered (*smart products)* (Dalenogare et al., 2018). The first considers technologies for the production process while the latter is related to the product offering. For the sake of completeness, in *Figure 2* it is possible to have an overview of different categories that compose *Smart Manufacturing* and *Smart Products.*

Categories	Technologies for Smart Manufacturing	Reference
Vertical integration	Sensors, actuators and Programmable Logic Controllers (PLC)	Jeschke et al. (2017); Lee et al. (2015)
	Supervisory Control and Data Acquisition (SCADA)	Jeschke et al. (2017)
	Manufacturing Execution System (MES)	Telukdarie et al. (2018); Jeschke et al. (2017)
	Enterprise Resource Planning (ERP)	Jeschke et al. (2017)
	Machine-to-machine communication (M2M)	Gilchrist (2016)
Virtualization	Virtual commissioning	Mortensen and Madsen, (2018); Tao et al. (2018c)
	Simulation of processes (e.g. digital manufacturing)	Jeschke et al. (2017)
	Artificial Intelligence for predictive maintenance	Tao et al. (2018c)
	Artificial Intelligence for planning of production	Gilchrist (2016)
Automation	Machine-to-machine communication (M2M)	Gilchrist (2016)
	Robots (e.g. Industrial Robots, Autonomous Guided Vehicles, or similar)	Gilchrist (2016)
	Automatic nonconformities identification in production	Gilchrist (2016); Jeschke et al. (2017)
Traceability	Identification and traceability of raw materials	Angeles (2009)
	Identification and traceability of final products	
Flexibility	Additive manufacturing	Weller et al. (2015); D'Aveni (2015)
	Flexible and autonomous lines	Balogun and Popplewell (1999); Wang et al. (2016a)
Energy management	Energy efficiency monitoring system	Gilchrist (2016); Kagermann et al. (2013)
	Energy efficiency improving system	Jeschke et al. (2017); Kagermann et al. (2013)

Figure 2. Smart Manufacturing and Smart products technologies. Source: Frank et al. (2018)

It's worth noting that, *Smart Manufacturing* is the central dimension of this group, and all other parts are linked with this one. Moreover, in this framework also is inserted how raw materials are transformed and products are delivered (*Smart Supply Chain*) and how workers practice their activities thanks to emerging technologies (*Smart Working)* (Stock et al., 2018). Also, in this case, we have some front-end activities being that the goal is a

significant contribution to the performance of the company. In other words, the focus is on increasing efficiency in operational activities. As in the previous scenario, a list of technologies for both are provided in *Figure 3.*

Technologies for Smart supply chain	References
Digital platforms with suppliers	(Pfohl, Yahsi and Kurnaz, 2017; Angeles, 2009; Simchi-Levi et al., 2004)
Digital platforms with customers	
Digital platforms with other company units	
Technologies for Smart working	**References**
Remote monitoring of production	(Wang et al., 2016a; El Kadiri, 2016; Zhong et al., 2017)
Remote operation of production	
Augmented reality for maintenance	(Elia et al., 2016; Scurati et al., 2018)
Virtual reality for workers training	(Elia et al., 2016; Gorecky, Khamis and Mura, 2017)
Augmented and virtual reality for product development	(Elia et al., 2016; Tao et al., 2018b)
Collaborative robots	(Du et al., 2012; Wang et al., 2015)

Categories	Technologies for Smart products	Reference
Capabilities of Smart, connected products	Product's connectivity	(Porter and Heppelmann, 2014)
	Product's monitoring	
	Product's control	
	Product's optimization	
	Product's autonomy	

Figure 3. Table of technologies for Smart Supply Chain and Smart working. Source: Frank et. al (2018)

The second group is composed of *"Base technologies"* and, as the name suggests, is the base on which Front-end functions are developed providing intelligence and connectivity. This set of technologies is composed of the so-called ICT: Internet of Things, Cloud Computing, Big Data, and Analytics (Wang et al., 2016). Furthermore, this is also what signs the difference between Industry 4.0. and previous stages of manufacturing.

These components will be further analyzed in the following chapters.

1.2. Background of servitization

"*Service business model innovation is the product of a servitization strategy, where a manufacturing firm with a product business model expands its offering into services related to its products and, as a result, shifts from the "product-only" business model to the "service-oriented model*" (Cusumano et al., 2015).

A first important point is to underline that not all services applications remain homogeneous through the innovation process, and it is not uncommon a situation in which this kind of offering is hybrid. Ulaga and Reinartz (2011) studied this kind of categorization using a matrix for manufacturing firms' offerings, thanks to case studies and depth interviews with senior executives in manufacturing companies. This classification is based on the nature of the recipient (supplier's product or client's processes) and the nature of the value proposition (input-based or output-based). Combining these two dimensions it is possible to identify four services categories that imply different combinations of goods and services and differ in key resources, capabilities, and success factors.

Product life cycle service (PLS). In this case, the service is directly correlated with the supplier's product. It refers to the set of services that can assist the progress of customer's ingress to manufacturer's good and guarantee its correct function in the entire life cycle. When we think about which the simplest way is to exploit the installed base this is one of those examples. PLS are frequently considered a "must-have" so the willingness to pay for this kind of service is not much higher. They are often a prerequisite to expanding into other categories. Moreover, a large share of big manufacturing firms' turnover is based on these services

Asset Efficiency services (AES). The next step in transitioning to servitization is the one in which the attention is on the performance of the product. It can be defined as *"the range of services suppliers provide to achieve productivity gains from assets invested by customers"*. As we can deduce, the objective is to manage something related to the product but is not a basic service, instead, it consists of maximizing the efficiency of your product. Compared with the previous strategy, there is a change in the value proposition from the "deed" with the customer to performance-related asset productivity. Moreover, the level of standardization compared with the previous one is lower. Some examples are predictive

maintenance, on-site or remote condition monitoring. Moreover, AES is not perceived as a must-have, on the contrary, it allows the perception of services to be sold separately. It also causes an increase in the willingness to pay for it.

Process support services (PSS). It is defined as "*the range of services a manufacturer provides to assist customers in improving their business processes*". The value proposition focuses on increasing the efficiency of the customer without taking direct responsibility for it or conducting the process on their behalf. The supplier leverages its resources and competencies to help the customer manage its processes. This strategy includes a range of advisory and consultancy services like auditing and optimization. The supplier makes an assessment and gives recommendations. Finally, this type of service is generally priced as professional services (generally not linked to performances), and the willingness to pay tends to be high. To have success in this field, manufacturers usually strengthen service-related data processing and understanding of their customers' processes.

Process delegation services (PDS). PDS is a combination of goods and activities that suppliers integrate to perform processes on behalf of the customer. In the paper, it was defined as "*the range of services a manufacturer provides when it performs processes on behalf of the customer"*. As in the previous case, the object is the process but unlike PSS, the focus is on the promise to achieve a certain performance (i.e., output-based). The supplier takes control of the process, sometimes also on behalf of the customer. Those solutions can be narrow or complex (end-to-end processes or full-service agreements). Only a few suppliers hazard on selling these kinds of services, due to the complexity of the capabilities needed.

Classification Scheme of Industrial Services for Hybrid Offerings

Nature of the Value Proposition	Service Recipient: Service Oriented Toward the Supplier's Good	Service Recipient: Service Oriented Toward the Customer's Process
Supplier's promise to perform a deed (input-based)	**1. Product Life-Cycle Services (PLS)** *Definition* •Services to facilitate the customer's access to the supplier's good and ensure its proper functioning during all stages of the life cycle *Examples* •Delivery of industrial cables •Inspection of an ATM machine •Regrooving of an industrial tire •Recycling of a power transformer *Primary Distinctive Capabilities* •Hybrid offering deployment capability •Design-to-service capability *Main Underlying Resources* •Field service organization •Product development and manufacturing assets	**3. Process Support Services (PSS)** *Definition* •Services to assist customers in improving their own business processes *Examples* •Energy efficiency audit for a commercial building •Logistics consulting for material-handling processes in a warehouse *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Hybrid offering deployment capability •Hybrid offering sales capability *Main Underlying Resources* •Installed base product usage and process data •Field service organization •Product sales force and distribution network
Supplier's promise to achieve performance (output-based)	**2. Asset Efficiency Services (AES)** *Definition* •Services to achieve productivity gains from assets invested by customers *Examples* •Remote monitoring of a jet engine •Welding robot software customization *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Hybrid offering sales capabilities *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets	**4. Process Delegation Services (PDS)** *Definition* •Services to perform processes on behalf of the customers *Examples* •Tire fleet management on behalf of a trucking company •Gas and chemicals supply management for a semi-conductor manufacturer *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Design-to-service capability •Hybrid offering sales capabilities •Hybrid offering deployment capability *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets •Product sales force and distribution network •Field service organization

Figure 4. Classification scheme of industrial Services of hybrid offerings. Source: Ulaga et al. (2011)

Commonly, the path of the innovation strategy that a firm adopts starts with product-related services managed directly on the product (i.e., maintenance and supervise), to successively develop customer-related services that promote the optimization of customer processes connected with a commodity usage (i.e., training or consulting) (Raddats & Easingwood, 2010).

Another important point is that nowadays, companies in the manufacturing sector are using this kind of practice to innovate. Contradictory results were presented about the fact that the relationship between servitization and product innovation may not be entirely complementary (Visnjic et al., 2016). Anyway, there is a wide consensus that this strategy

brings strategic and competitive benefits for companies that decide to adopt it (Ayala et al., 2017). One of the most challenging steps to understand the new value proposition is to be fully able to understand its impact on the business model (Ayala et al., 2017).

1.3. Convergence of Servitization and Industry 4.0.

The purposes of this convergence of concept performed by Frank et al. (2019) are many. Firstly, to identify which are the different types of servitization accordingly with the digital technologies used. Then, to understand the implications of different strategies and BMIs, and finally to provide some examples of applications. To link Servitization and I4.0., Frank et al. (2019) developed a model based on the previously available literature. They considered two different BMI forms: *digitization level* (valuation of the implementation of technologies included in I4.0) and *servitization level* (considering the importance inside the firm of different services offerings). *Digitization* is defined by the authors as "*the transition process companies are facing when they progressively adopt digital technologies to achieve an interconnected smart enterprise as proposed in the Industry 4.0. concept*".

These two components differ in the type of push, the first one follows a technology-push trajectory while the second one follows more a demand-pull trajectory. The result of this differentiation can be visualized in the matrix (*Figure 5)*

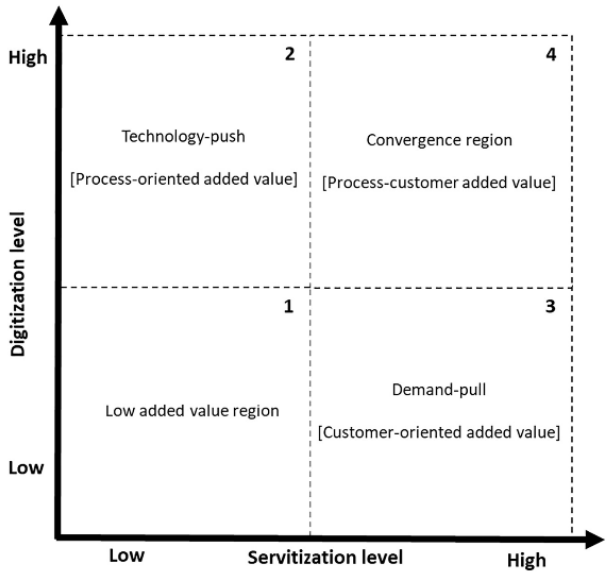


Figure 5. Innovation trajectories for Industry 4.0. and Servitization. Source: Frank et al. (2019)

Moreover, the authors proposed a categorization of Service offerings accordingly with the scope of the service offered by the product firms.

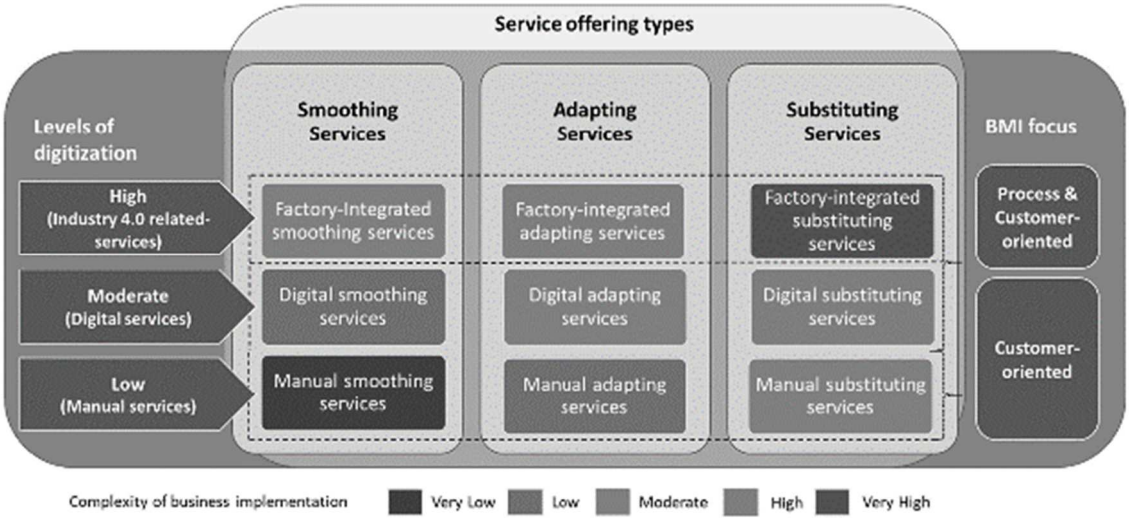


Figure 6. Conceptual framework for Servitization and I4.0. Source: Frank et. al (2019)

Levels of digitization are divided into three categories. The lower two are characterized by a customer-oriented strategy while the higher is focused both on the customer and the process. As represented, the first grade is composed of *manual services* that are service offerings in which digital technologies are used only as developing support and do not represent a service *per se*. Then we have *digital services* when there is a situation in which the degree of servitization is higher and technologies are used to provide a service, adding a certain value to the solution.

At the top of digitization, we find Industry 4.0. related services, which include high-tech functions. Only with the highest level of digitization which follows the concept I4.0., is seen as a new industrial maturity stage of product firms.

As we can see in *Figure 6* this classification leads also to identification of different types of services that can be divided into three groups. Inside each of them, services are increasingly I4.0. related.

> *Smoothing services.* Inside this group, we can find all these services which share a technology-push BMI since the predominance of the services in these product firms are not the highest. These can be positioned in Quadrant 1 and 2 of Figure 5.0.

Adapting services. In the adapting services, the three configurations are a mix between high-technology push innovation and a medium market-pull innovation. Identified in between two Quadrants of Figure 5.0: 1 and 3.

Substituting services. This last group is the only one that strictly follows the I4.0. concept. Moreover, these follow from a high technology push to a convergent technology push. Positioned in the Quadrants 3 and 4 of Figure 5.0.

The framework proposed by Frank et al. (2019) is also characterized by different levels of BMI complexity accordingly with the level of change needed to implement these services. Furthermore, they followed the idea that there is an increasing complexity based on the change that a company develops. The more a company moves toward servitization more the complexity of the process increase (Cusumano et al., 2015).

2. Set of technologies

In previous chapters, we analyzed the general concept of Industry 4.0. and all its implications from a theoretical point of view. Anyway, in the field of servitization and I4.0. many articles focused on the analysis of a set of technologies that populate nowadays the business scenario.

In the following paragraphs we are going to describe, just to name a few, Data Analysis and Big Data, AI and Machine Learning, System integration, IoT, Cybersecurity, Cloud, Additive Manufacturing (3D printing), and Augmented Reality. All these technologies are investigated in the survey that we are going to further analyze.

2.1. IoT

Internet of Things (IoT) can be defined as a network of physical objects that interact with each other to share information and act. It can be also defined as the third wave of Internet development (Rymaszewska et al., 2017). Another possible definition is the following: *"IoT is a dynamic network framework which intends to coalesce the physical and the virtual domains by utilizing the internet as the medium for communication and transmission of data between them"* [1].

In all the different meanings of the Internet of Things, the common factor is that it is related to the connection between the physical world and the virtual world of the Internet. Some examples of devices include RFID readers, sensors and actuators, embedded computers as well as mobile phones. (Haller, n.d.).

Da Costa (2010) affirmed that traditional networking architectures are not sufficient to handle the huge scale of IoT. The architecture of the IoT can be explained by dividing the network into three different areas:

- *End devices.* It is the final technology.
- *Propagator codes.* It ensures transport and gateways to the traditional Internet
- *Integrator functions.* It enables analysis and control

Moreover, Gubbi et al. (2013) indicate three main components that enable IoT:

- *Hardware.* A collection of sensors, actuators, and embedded communications components

[1] School of electrical engineering, VIT University, India

- *Middleware.* On-demand storage and computing tools for data analysis
- *Presentation.* Visualization and interpretation tools, novel, easy to use

In addition, it usually refers to technologies linked with sensors able to communicate with one another. IoT offers an important opportunity to the firm to know better how their customers use their products also increasing the proximity with them. In addition, it is possible to create a network of things that communicate without the help of humans (Rymaszewska et al., 2017). In their research, they affirmed that every value activity is composed of a physical and by an information-processing component. With the technological development that occurred in the last few years the cost decreased, and many industries moved towards information content in products and processes. It is possible to link this concept with servitization.

The impact of IoT on value creation was commonly discussed in the academia. A field of research proposes that digitalization can positively influence servitization. The paper proposed by Rymaszewska et al. (2017) followed this stream of view and affirmed that IoT solutions can be an important tool to construct the product-service system in the future. Moreover, the value creation generated using reliable data about product usage and performance is fully validated by many papers as Coreynen et. al. (2016).

As previously mentioned, one of the most important factors linked with IoT is how it can influence value creation and, generally, can lead to some important benefits. In this context, we can identify two main challenges. The first one is that it is important to offer services that are related to the customer's needs, while the second one is that these services must be differentiated to build a competitive advantage.

IoT is strictly linked with other technologies that will be further described in the following chapter as Cloud computing, Big data, and big data analysis.

2.2. Cloud

Cloud computing is becoming rapidly one of the most important technologies in the world offering many opportunities to many business sectors. The definition of cloud computing is debated but can be defined as a "*remote environment from Information Technology perspective"* which *"usually provides a single, simple interface for the users to use and hide the architecture"* (Xue & Xin, 2016).

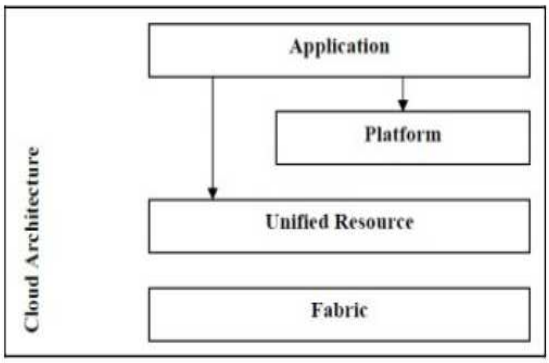


Figure 7. Cloud architecture. Source: Xue & Xin (2016)

Cloud architecture is composed of four main layers

Fabric. It is composed of physical, computational devices and hardware resources such as storage systems.

Unified resource. It is composed of virtualized resources that act as integrated resources. Moreover, physical machines are encapsulated to act as integrated resources for the end-users.

Platform layer. Here are inserted technologies as specialized tools, middleware, and services to decrease the number of deploying applications in virtual machine containers.

Application. It represents the applications, usable by the users, which are executed and run in the cloud.

Cloud services do not need any on-premises software to be executed, on the contrary, are accessed with any provider and 24/7.

Cloud computing can be classified accordingly with some models: Service as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

In SaaS service providers will set up their software applications that are managed by the consumer to use as a service. The firm can rent it or opt for a pay-per-use model. In addition, the users can approach the Cloud without any concern of installation and maintenance without the need to perfectly know about infrastructure and platforms. Another pro of this model is its scalability, compatibility, accessibility, and hardware

resources. On the contrary, users cannot customize and do not have control over components and security.

In the second model, PaaS, the development environment will be provided by the service provider and there is the chance to implement and maintain applications. More in detail, software, hardware, operating system, server, development tool, and database are given to the customer. Some examples of PaaS are AMS, Google App Engine, and Microsoft Azure.

The last model, IaaS, has as main concept virtualization. Here the service provider gives the infrastructure for the application to run storage, processing unit, networks, etc. The most important advantage in this situation is that the users bear no responsibility in deployment, administration, and maintenance.

In addition, the cloud can be also divided into two main categories (which have also some sub-categories) public and private cloud.

In the public Cloud the services are offered to everyone over the Internet, and, in our specific situation, a Cloud service is shared also with other firms. It is not unusual that in this case there is a policy, value, costing, and charging model are common.

On the other hand, private cloud service is for business utilization with higher security.

As previously mentioned, the usage of Cloud Computing in business was proved to create value due to some characteristics that it can enhance.

The first benefit is the flexibility that it can create. Also, in the covid situation was easily understandable that free access to a Cloud environment was able to manage a new way of working: immediate file sharing, accessibility from everywhere, and aligned information.

One of the main reasons to opt for Cloud Computing was proved to be cost reduction (Resa et. al., 2013). It was due to pay-per-use contracts specifically in subscription models, quick deployment, and installation, shift in IT responsibilities to the providers (savings on training). Moreover, the low initial investment results in a lower entry barrier. This is strictly linked to efficient management of software and hardware upgrades which helps also in technological advances, increases profit, provides standardized services to customers (Abdulaziz et. al., 2012).

As previously mentioned, also the availability of the Cloud is a representative characteristic of Cloud computing. This leads to a major hit on delivering services.

Lastly, scalability allows the user to adjust resources on going expanding infrastructure (Buse R. F., 2011). It results also in a bigger advantage to SMEs which can rapidly increase their necessary resources.

2.3. Data Analysis and Big Data

Strictly linked with the precedent argument another factor of interest is represented by Data Analysis and Big Data.

Big Data is defined by Gartner as *"high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making."*.[2]

The latter is becoming related to almost all aspects of human activity from just recording events to research, design, production, and digital services or products delivery to the final consumer. Current technologies (explained also above) give infrastructure to create a platform for automation of all processes in data collection, storing, processing, and visualization (Smari et al., 2014). In their paper, Smari et. al. (2014) also proposed a table representing big data origin and target use domains:

TABLE 1. BIG DATA ORIGIN AND TARGET USE DOMAINS

Big Data Origin	Big Data Target Use
1. Science	(a) Scientific discovery
2. Telecom	(b) New technologies
3. Industry	(c) Manufacturing, process control, transport
4. Business	
5. Living Environment, Cities	(d) Personal services, campaigns
6. Social media and networks	(e) Living environment support
7. Healthcare	(f) Healthcare support

Figure 8. Table of Big data origin and target use. Source: Smarti et al. (2014)

As we can see one of the main big data target uses is the Manufacturing and process control field.

[2] Big Data defintion, Gartner, Inc. [Online]. Available:http://www.gartner.com/it-glossary/big-data/

Nowadays they represent one of the most valuable organizational resources. Recently, much research started to empirically show the impact that they have on organizational outcomes such as agility, innovation, and competitiveness (Mikalef et al., 2019).

One of the acknowledged points of interest in this field is that to obtain a real benefit from data analysis and big data companies must be aware of which areas can identify the benefit of this kind of process.

2.4. Artificial Intelligence (AI) and Machine Learning (ML)

Linked with the previously analyzed concept also AI and ML are important technologies increasingly used in many manufacturing firms.

Artificial intelligence is defined as a union of technological components that collect, process, and act on data imitating human intelligence. Moreover, they can learn over time and adapt (Russel and Norvig, 2016). In other words, it can be defined as the use of a set of devices aimed at recreating the cognitive abilities of humans to achieve a specific aim autonomously.

AI Applications have a use in a range of increasing sectors and have three shared components. The first is the input data also composed of a large volume of data that can be also very heterogeneous. It is possible to use real-time data (via physical sensors or online activities), historical data, images, speech, and so on. (Canhoto & Clear, 2020)

The second component is the machine learning algorithm defined as the computational procedure that processes the data inputs. The machine learning process can be divided into three different types: supervised, unsupervised, and reinforcement.

The first type defines a situation in which human experts give to the computer some sort of training data set with inputs and correct outputs. In this way, the computer can understand the right possible patterns and autonomously develop some rules applicable in the future to solve a similar problem (Canhoto & Clear, 2020).

On the other hand, in unsupervised learning, a set of training data is given to the computer but with the difference that there are no labels. Here, the algorithm's goal is to search for the best way of grouping the data points and assess how these are connected.

The last form is reinforcement learning, in which the algorithm is given a set of training data and a goal. The objective is to find the best combinations of actions to achieve the

specified goals. To do it, some criteria are given to judge alternative courses of action and rewards for actions that are needed.

In the *Figure 9* it is possible to see also some examples of the above-mentioned types of machine learning.

The last component of AI is the output decision resulting from the algorithm. This can produce a single result or a selection of it that has no performative value until an analyst act on it, but also a set of results. Finally, AI technology can also have the autonomy to act based on the result without any kind of human involvement.

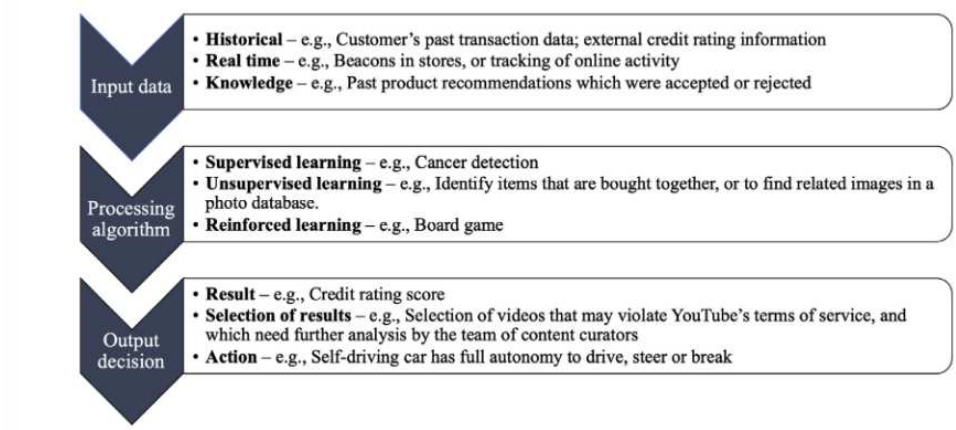


Figure 9. AI's components. Source: Canhoto and Clear (2020)

The increased usage of this technology is due to three main aspects: the introduction of more sophisticated algorithms, the spread of low-cost graphics processors able to compute a large amount of data in a restricted time, and the existence of very large databases (Wamba-Taguimdje et al., 2020). This series of conditions lead to the spread of this practice in many organizations. In their paper, Kuzey et al. (2014), view AI as a key growth factor able to increase the efficiency of operations, maintenance, and supply chain, optimize and improve customer experience, improve services and products, and as an item recommendation process.

2.5. Additive Manufacturing

Additive manufacturing (AM), is defined by the American Society of Testing and Materials (ASTM) as *"the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies; Synonyms: 3D printing, additive fabrication, additive process, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication.*" (ASTM

International, 2012). It was launched in the 1980s and it has been introduced in many industries such as automotive, aerospace, electronics, and so on. (Niaki & Nonino, 2017)

Process categories	Technology	Materials
Binder Jetting	3D Printing Ink-jetting S-Print M-Print	Metal Polymer Ceramic
Direct Energy Deposition	Direct Metal Deposition Laser Deposition Laser Consolidation Electron Beam Direct Melting	Metal: powder and wire
Material extrusion	Fused Deposition Modeling	Polymer
Material Jetting	Polyject Ink-jetting Thermojet	Photopolymer Wax
Powder bed fusion	Selective Laser Sintering Selective Laser Melting Electron Beam Melting	Metal Polymer Ceramic
Sheet lamination	Ultrasonic Consolidation Laminated Object Manufacture	Hybrids Metallic Ceramic
Vat photopolymerization	Stereolithography Digital Light Processing	Photopolymer Ceramic

Figure 10. Classification of process categories, technologies and materials. Source: ASTM (2012)

In the paper developed by Niaki and Nonino (2017), they investigated the role of AM in business strategies and performances. The AM process involves stereolithography (SLA)[3], selective laser sintering (SLS)[4], fused deposition modeling (FDM)[5], laminated

[3] Stereolithography is a 3D Printing process which uses a computer-controlled moving laser beam, pre-programmed using CAM/CAD software. Source: https://www.protolabs.co.uk/services/3d-printing/stereolithography

[4] SLS is "technique that uses a laser as the power source to sinter powdered material (typically nylon or polyamide), aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure" https://en.wikipedia.org/wiki/Selective_laser_sintering

[5] FDM is a technology where the melt extrusion method is used to deposit filaments of thermal plastics according to a specific pattern. Source: https://www.sciencedirect.com/topics/materials-science/fused-deposition-modeling

object manufacturing, ballistic particle manufacturing[6], and desktop three-dimensional printing (3DP).[7]

Another possible classification is given by the ASTM in 2012, in which the range of AM technologies is classified into seven categories.

The *Figure 10* reports this alternative possible classification.

Many studies demonstrated some important advantages in the use of AM in many industrial sectors as small size, small volumes, and very complex parts. In addition, the usage of these technologies offers a chance to fully customize products.

Using multiple case studies Niaki and Nonino (2017) tried to identify the key variables and the linkage between AM usage and company performance. AM was perceived to have a conditional impact on competitiveness, energy consumption, and duration of ROI based on the involved product's characteristics.

They found out that SMEs that implemented it affirmed that it boosted their competitiveness. Moreover, those who used metal as row material reduced more energy consumption compared to those who used conventional manufacturing.

As for other technologies, learning by doing may have helped companies that previously introduced this type of technology.

Lastly, the type of material used influenced the payback. In other words, companies using AM for RP with plastic material have a longer payback period in comparison with conventional manufacturing companies.

2.6. Augmented Reality

Augmented Reality (AR) identifies a set of technologies that permits the view of the real-world environment to be "augmented" by computer-generated elements or objects. (Van Krevelen & Poelman, 2010). It appeared for the first time in the 1960s but the term will not be created until 1992. At that time two scientists developed an AR system to help workers to unify wiring harnesses.

[6] BPM "utilizes ink jet or droplet-based manufacturing techniques, where it builds the models by firing micro-droplets of molten wax material from a moving nozzle or jet onto a stationary platform, the platform then lowers and the process is repeated for each layer of the model"
[7] It is a process of making three dimensional solid objects from a digital file

More in detail, it describes a mediated reality in which the use of visual perception of the real environment is boosted using computer devices (Bottani & Vignali, 2019).

Former research in the field classified some possible contexts of usage of this technology: medicine, maintenance, annotation, robotics, entertainment, military, learning, and education.

Only in 2011, Georgel coined the term industrial augmented reality (IAR), to define the specific use of AR to assist manufacturing in some of the most important parts of the process (maintenance, assembly, and training). The need for real-time information due to globalization and always faster supply chain led to the increasing use of augmented reality in the production process. In this perspective, AR is a big help thanks to the capability to simulate, assist and improve the company's processes before they are carried out.

A typical AR system is composed of some fundamental components as the capturing/visualization device, the interaction device, and the tracking system (Jeon et al., 2010).

The capturing device is a technological solution needed to capture the scene and collect information about the environment. Additionally, the visualization device is used to display the image that is created by the union of the real environment and the additional information.

Interaction devices are necessary for commands while tracking technologies are needed to let the system recognize the key components and the user's position.

Concerning the outcome of the usage of these technologies, in their bibliography review paper, Bottani&Vignali (2018) affirm that in many of the analyzed research the outcome measured was more than one. More in detail, many papers focused on the effectiveness of the solution developed intended as savings in the time required to carry out a given task, effectiveness and ease of usage, and the possibility to reduce errors.

Combining all the results, they found out that assembly and maintenance benefit from faster execution of tasks.

3. Service business model innovation (SBMI)

3.1. Internal and external factors in servitization

In the first Chapter, we analyzed the linkage between Servitization and Industry 4.0. from a theoretical point of view. As, we saw these relationships are stronger when the chosen solutions are based on an added value deriving from customer-based and process-based solutions (Frank, Mendes, et al., 2019a).

Now, we want to focus on these factors, both internal and external, that have a leading role in the shift to servitization.

Firstly, we must define what internal context implies. Ziaee Bidgeli and Baines (2017), in their model, used as internal context characteristics the *organizational maturity* and the *capability dimension*. The first one embodies the sophistication of the managing practices and their impact on the servitization strategy (i.e., informed decisions about servitization strategies). For organization capability, they intend to define those skills that a manufacturer needs to design and deliver services (Baines et al., 2017).

On the other hand, the external context stands for the ecosystem, market, and technology dimensions. The *market* expresses the economic environment in which a firm operates. The *ecosystem* dimension captures a firm's position in the value chain, involving the relationship that a firm has with its customers and final users. The last dimension, the *technological*, involves this set of emerging technologies and processes that can have an impact on servitization.

Anyway, additional characteristics are necessary to develop and analyze servitization challenges (Dmitrijeva et al., 2020). In their research, they expanded the model defined by Baines et al. (2017). In the following table, a list of dimensions and related themes is presented.

Table 1. Internal and External dimensions of the impact in servitization. Source: Dmitrijieva et al. (2020)

Dimensions	*Themes*
Maturity dimension	Leadership, organizational culture, power, and politics, operational and strategic alignment, change acceptance
Capability dimension	Service development capabilities, product-focused capabilities, learning capabilities, innovation capabilities, and complexity management

Market dimension	Customers' requirements and tastes, economic and trading conditions, customer relationships, legal requirements, market prudence
Ecosystem dimension	Supply chain control, open knowledge networks, collaboration practice, industry-level platforms, network competition
Technology dimension	Information technology, product technology connectivity, sensor integration, analytics

Much research adopted a metamorphic perspective in the servitization process. The already mentioned paper by Ziaee Bigdeli and Baines (2017) defines it as the *"organizational transformation towards servitization model which conceptualizes the transformation process along four stages (exploration, engagement, expansion, exploitation)"*. In this sense, they focused on the processes carried on by a manufacturer in the transformation to become a service provider. As expressed by Baines et al. (2009) this transition involves a change in the goals, structure, skills, and culture of the company. The first step describes an initial learning process towards servitization, this is completed when the firm is sure that conversion through servitization is practicable. The following step consists of the systematic evaluation and communication of the business transformation. The *expansion* stage involves an increase in the service offered by the firm. Finally, in the last step, the *exploitation* one, a company provide a set of service that can ensure valuable competition.

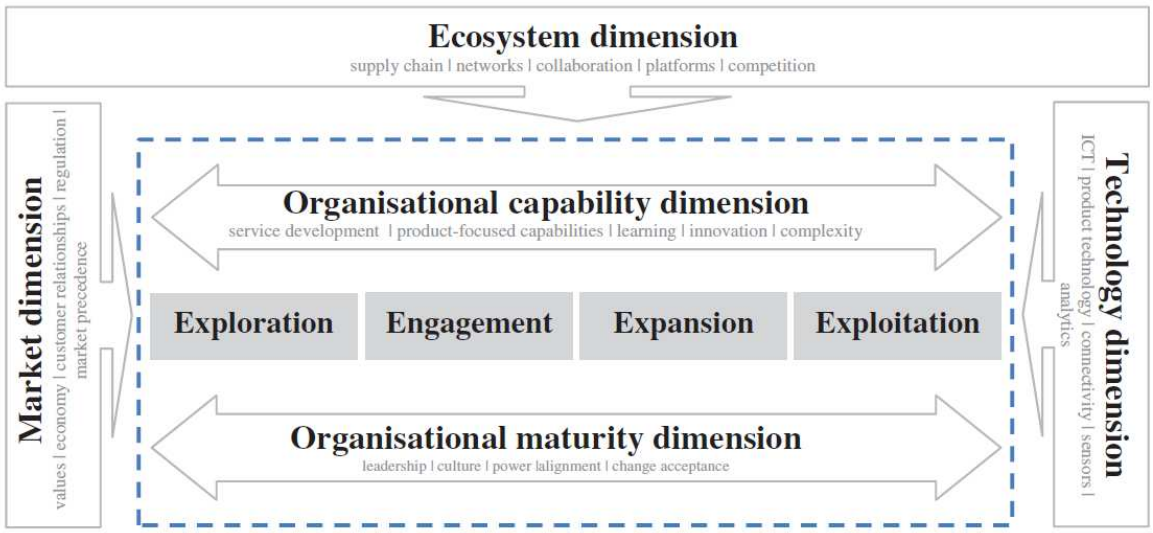


Figure 11. Theoretical framework for servitization process. Source: Dmitrijeva et al. (2020)

Being that the goals and activities transform during these steps it is predictable that the effect of the context factors in the above-mentioned domains can change too. (Dmitrijeva et al., 2020). In Figure *11* we can also see how these dimensions affect different stages of the servitization process.

In the paper, they defined as in the *exploration* phase most of the factors were linked with organizational maturity and capability dimensions (i.e. the sophistication of the manufacturer's management practice). Conditions as key stakeholders or senior management were fundamental in the first part of the transition.

In the second step, the *engagement*, most relevant factors fell into the organizational maturity dimension (leadership-related factors, enthusiasm in the company). Moreover, some factors identified were from the capability dimension. For example, the necessity by the company to understand and integrate customer requirements. Finally, also in this phase, some market factors resulted important as regulatory changes able to help the progress. Finally, they identified technology immaturity as an impacting factor.

In the *expansion phase* factors coming from the maturity dimension (i.e. general strategy, capacity to learn from pilots), capability dimension (i.e. service marketing skills), market dimension (i.e. market reaction), and ecosystem dimension were discovered.

The latter dimension was identified through the crucial necessity of collaboration across the value chain and the share of competencies and assets.

The last phase, *exploitation*, involved maturity dimension (assessing and changing the firm's structure to continue in the progress) market dimension (impact of the loss of customers), capability dimension (importance of strong delivery efficiency and reliability), and the ecosystem dimension (entrance of new players in the market).

One of the most interesting results is how technology, frequently highlighted in the literature as one of the most important parts of the process, is defined only in one specific stage, that is *engagement* stage.

3.2. SBMI and product-service systems BMI

Recently, business model innovation received a large empirical and theoretical interest. It also influenced many areas such as innovation management, entrepreneurship, and marketing.

Amit and Zott (2012) define a business model as a system of interconnected and interdependent activities that define how a company "does business" with its customers, partners, and vendors. In addition, *"business models show how organizations design and conduct activities to provide value to their customers"* (Müller et al., 2018).

There are six functions of a business model (Chesbrough, 2007):

1. *Define the value proposition*
2. *Identify the market segment*
3. *Define the value chain structure and the complementary assets needed to support it*
4. *Specify the revenue generation mechanisms of the firm and estimate the cost structure and profit potentiality*
5. *Describe the position of the firm in the network (ecosystem)*
6. *Create a competitive strategy through innovation to gain and hold the advantage*

As previously mentioned, industries are changing in the last decade how to do business with clients and how products are developed, manufactured, and delivered. Servitization and Industry 4.0. are two phenomena that can certainly affect the business models (BMs) of product firms. (Frank, Mendes, et al., 2019b). Another definition, proposed by Foss and Saebi (2017) describes BMI as the "*designed, novel, non-trivial changes to the key elements of a firm's business model and/or the architecture linking these elements"*.

Innovation in service science was investigated by Maglio and Spohrer (2013). Through this science, they combined organization and human knowledge with business and technological understanding defining the four basic principles of service science. In other words, they defined not only how service systems are composed but also how the relationships between components in these systems are based on the value proposition.

In addition, were investigated how interactions are based on access to resources and how these interactions depend on symbol processing.

Going more into details, concerning the service business model innovation (SBMI) we can affirm that it is the product of a servitization strategy in which a manufacturing company, with a product BM, extends its offering in the service-related fields. As a result, there is a shift from the product-only business model to a service-oriented model. (Visnjic et al., 2016). In 2017 Kowalkowski et al. affirmed that the servitization strategy results in a transformation from a product-centered firm to a product-service system (PSS). Continuing, the goal of PSS is to value asset performance of product and service instead of ownership and differentiation. Meier and Massberg (2004) developed the concept that PSS provide a solution able to integrate products, services, and business models (Vasantha et al., 2012).

As previously reported, Frank et al. (2019) considered both servitization and Industry 4.0. in this context.

In their paper, Müller et al. (2018), analyzed how Industry 4.0. can affect the three business model innovation elements: value creation, value capture, and value offer. In their work, a business model is defined as the sum of these three mechanisms. They analyzed 68 German SMEs conducting qualitative research.

Accordingly, with their work, value creation addresses the task that a company carries out to provide an offer to the customer. The second, value capture, is how a company can sustain itself through monetization of the offer and commercial activities. The last, value offer, is the set of products and services that each company is involved in their activities.

Value creation	Value offer	Value capture
Production equipment (26) - Productivity increases - Energy savings - Load balancing - Higher fault resistance of production equipment - Fast access to manufacturing data - Machine-health monitoring - Self-controlled production - Increased in-house production - Lower stocks - Easier production maintenance - Retrofitting of older machinery and new equipment required Workforce (22) - Attenuation of job shortages in manufacturing, yet likely shortages in Industry 4.0-qualified personnel - Better integration of lower qualified and elderly personnel - New job profiles - New workplaces - Higher technical expertise and employee trainings required - Technology-based trainings - Support in failure recognition - Decreasing number of manufacturing jobs Partners and suppliers (16) - Higher inter-company connectivity - Co-design of the value offers - Joint data analysis - Higher information transparency - Higher delivery reliability - Innovative partnerships - Increased virtual contact - Higher standardization required	Products (20) - Larger product spectrum - Less maintenance required - Versatile, flexible products (particularly machines) - Higher quality and output of the produced machines - Incorporation of manufacturing data in products and in production management systems - Products tailored to customer demands - Human-machine-interfaces Services (15) - Machine retrofitting services - Condition monitoring - Remote maintenance - Digitization services for customers - Data analytics services - Manufacturing and product simulations - Virtual product development - Engineering and product configuration services	Customer groups (11) - New customer groups addressed within the B2B customer base - Both the risks and the opportunities for customer retention are intensified Customer interaction (23) - Customer contact via digital platforms - Eased interaction through digital communication - Co-design and co-engineering - Higher cost transparency - Joint decision-making - Value chain integration of customers - Suppliers become more transparent to customers - Decreases in customer loyalty due to higher anonymity Payment methods (12) - Digital accounting and automated invoices - Increased payment reliability - Streamlined payment documentation - Increase in subscription models, pay-per-use and pay-per-feature

Figure 12. Impact on value creation, value offer and value capture of different conditions. Source: Muller et al. (2018)

The impact of Industry 4.0. on business model innovation was expressed into these three areas of values. Concerning value creation, they found that three main areas of the company were affected: production equipment, workforce, and partners and suppliers. Regarding value offer, the two areas were products and services. Finally, value capture had three main groups of impact: customer groups, interaction, and payment methods. In the *Figure 12* the list of each characteristic and how these were impacted is presented.

A lot of literature was developed in this field and many recommendations were made to service-oriented manufacturing firms. For example, Visnjic Kastalli and Van Looy (2013) developed a model to underline three main pieces of advice to obtain the expected results. First, the need to create a product-service business model to create reciprocal spillovers between products and services, and secondly, the need to implement practice to increase customer proximity. Finally, the needed attention to the investment necessary to obtain long-term profitability that can enable economies of scale and learning effects.

Many product-service providers fight to find an effective business model to correctly reflect the presence of service in their company and to effectively create and capture value (Kastalli et al., 2013).

Linked with this issue, some literature investigated also a phenomenon called the 'servitization paradox'. Some studies presented the possibility of a decline in the overall performance linked with this type of BMI. (Visnjic Kastalli & van Looy, 2013)

As demonstrated previously business model innovation is a topic that generated large interest in academia in the last decade. Nevertheless, a concrete way to measure BMI is not affirmed and very few quantitative studies are made to assess some instruments able to effectively measure this variable.

In previous literature, a common and validated measure was not yet identified. Some used a multi-item scale able to distinguish between business models based on novelty and business models based on efficiency. Others utilized a proxy-based on firm websites. In some cases, the measurement was based on the activity effects, technological changes, and operating efficiencies through proxies of secondary data. (Clauss Thomas, 2016)

In 2016 Clauss used two large-scale samples of firms to fill this gap and to develop a systematical scale for business model innovation.

This model has developed accordingly with the three dimensions of BMs: value creation, value proposition, and value capture. Following the literature, every potential component of the BMI can be unified into 10 subconstructs of these three dimensions.

Value creation innovation components can be unified into new capabilities, new technologies, new processes and structures, and new partnerships.

Concerning the value proposition innovation, most of the components relate to new offerings, new customer segments/markets, new channels, and new customer relationships. The last value, value capture innovation, can be aggregated into new revenue models and new price and/or cost structures.

3.3. Impact of external relationships in SBMI

First, sources of information and knowledge determine the ability of a firm to adopt necessary innovations and to obtain a competitive advantage in the market.

The concept of innovation in firms was firstly linked to the role of research and development in business. On the other hand, nowadays many academical work link innovation to the presence of networks, relationships, and different forms of interactions with external players. (Powell and Grodal, 2005).

In addition, several works define external relationships as a fundamental factor able to enhance innovation performance in companies giving a relevance to "open innovation" (Rammer et al., 2009). The knowledges that can be acquired thanks to this type of relation can offer to firms new ideas and can enable more transfers (Lasagni, 2012). It helps to understand how external relationships can have an impact on the business model of a company.

In their paper, Dahlander and Gann (2010), started from a fundamental concept: a single organization cannot innovate in isolation. Internal capabilities of a firm and external relations are complementary inside the innovation path of a company. (Dahlander & Gann, 2010). According to Chesbrough (2007), the fourth step[8] in a business model innovation process is the one in which the company has an externally aware business model. In this context, a company starts to open itself to external ideas and technologies unlocking a large set of resources not previously available. This sort of new external relationship helps to identify projects and to fulfill needs. The effect of this innovation is that the company can perform a cost-saving strategy, but it can also reduce the time to market products and services. In addition, there is a share of the risk of new products and processes.

In this context, internal roadmaps are also shared with suppliers and customers frequently. It is necessary to unlock the systematic usage of innovative ideas. Moreover, it allows external entities to plan their activities in concert with the business.

Another important contribution of external relations can be given in the resource-based strategic management approach. External relations can be fundamental to education of the human capital of a company. Openness towards external knowledge sources and partnerships in training enhance companies to develop suitable solutions and procedures. (Stachová et al., 2019).

The empiric literature seems to confirm that cooperation has a positive effect on technological innovation.

[8] The roadmap proposed is composed of six consequently step: (1) company has an undifferentiated business model, (2) company has some differentiation in its business model, (3) company develops a segmented business model, (4) company has an externally aware business model, (5) company integrates its innovation process with its business model, (6) company's business model is an adaptive platform

Going more in detail, also in PSS projects external relations play a fundamental role in developing innovation. Particularly, in the solution-seeking phase to enable involvement of necessary resources. The participation of this external players enables the design of solutions seeking and the usage of joint problem solving. Interactions, collaborations and communication between the company, network partners, and customers have a high degree of importance (Wallin et al., 2015).

Finally, PSS BMI can be overall linked with the value proposition innovation. Most of the components relate to new offerings, new customer segments/markets, new channels, and new customer relationships. (Clauss Thomas, 2016). One of the recommendations to the companies is to develop close relationships with companies or subsidiaries to pursue an optimal PSS BMI. The goal is to organize alliances and networks to attract customers with the best offers and prices (Mont, 2001).

More recent literature also linked digitalization and servitization in the BMI context. Through a sample of 131 manufacturing firms was investigated the impact of the interaction between digitalization and servitization on financial performance. A necessity of interplay of these two components was discovered, so called, digital servitization (Kohtamäki et al., 2020). A particular u-shaped effect was reported consisting of a negative and significant financial performance impact from low to moderate levels of digitalization and high servitization. On the other hand, this impact become positive and significant from moderate to high levels of digitalization and high servitization. It emphasizes value creation through the interplay between product, services, and software.

This work seems also to confirm the positive impact of servitization on financial performance, a result that was too long debated in previous research.

Digital servitization (DS) represents a recognized key driver for business model innovation. Concerning this topic, also the role of external relationships and collaborations was widely investigated. Many are the results that seems to link successful digital servitization processes with the creation of external relationships and interactions with external actors.

To develop digital technologies and achieve digital servitization effective collaborations with customers and other actors involved in the ecosystem is required (Kohtamäki et al., 2021). In fact, external relationships with technology-oriented firms can contribute to the

success of the DS project (Paiola et al., 2021). Indeed, creating a collaborative environment that ensures precise and multifaceted collaborations between actors within an organization, as well as external actors, is critical to the successful implementation of digital servitization (Sklyar et al., 2019).

4. Empirical Research

The literature review reported in previous chapters seems to be confirmed the fact that servitization, industry 4.0. and service business model innovation play an interconnected role in the firm context. Many papers aimed to link these macro-phenomena. For instance, the linkage between digitalization and servitization was analyzed in the work by Kohtamäki et al. (2020), the relationship between servitization and industry 4.0. was discovered in the paper by Frank, Mendes, et al. (2019) and in the work by Ziaee Bigdeli and Baines (2017) the impact of external and internal factors on servitization was investigated.

On the other hand, too often academia seems to be focused only on one or two of these concepts lacking a comprehensive vision in which boundaries between these phenomena are no longer so obvious. The complexity of the contemporary market impels us to analyze the firm-related vision from a more relevant point of view analyzing more aspects of the involved firms both internal and external. Furthermore, since these arguments are relatively new and their implications in the market are continually transforming, confirmation about the results obtained previously in the literature is fundamental.

In addition, in the empirical studies, the role covered by internal and external factors in service business model innovation too often refers to sample of SMEs. It means, that empirical studies focus just on one category of firms with relatively low capabilities. The fact that often analysis and empirical studies concentrate on just one category makes it difficult to compare which are the paths that must be followed accordingly to the capabilities of different firms.

Moreover, the impact of external relationships on BMI in the recent literature focused majorly on digitalization not considering many other important factors that may have a linkage with the latter. For instance, the linkage with the end-user.

This work proposes to create a model able to enclose more conditions often linked to different phenomena. Accordingly, with underline assumptions of previous literature, it will involve human capital, technological capabilities, customer-related relationships but also firm-related capabilities.

Considering precedent discussions, this empirical study proposes to investigate the intensity of external relationships, seen as a relevant component to obtain successful business model innovation in the PSS field.

The survey involved SMEs and large companies in order to create a model able to give an overall vision of the paths that can be followed by both categories. To summarize the analysis wants to answer some specific research questions: “which are the conditions of a company that, combined, can impact the intensity of external relationships?” and “are these paths different for SMEs and large companies?”.

4.1. Survey methodology

The developed survey aims to investigate the PSS (Product-service system) progress of Italian manufacturing firms with questions about technologies, services, internal expertise, and current relationships with external providers. The purpose is to understand how companies perceive themselves toward the servitization process. This work was developed in collaboration with the Digital Lab, managed by the University of Padua.

The survey was proposed to a group of high-level managers, directors, and experts in 22 manufacturing Italian firms. All the respondents were linked with R&D, IT, post-sales, and managing activities. This specific sample was chosen for the purpose to have a high-level view of the internal process and to be able to capture the real status of the servitization process of their firm. *Table 2* presents a list of the role covered by each of the respondents.

Table 2. Role of the respondents involved in the survey

Company ID	Role of the respondents
ID1	CEO
ID2	Senior product manager
ID3	Group Chief R&D Officer
ID4	Group IT Manager
ID5	General Manager
ID6	Service director
ID7	Technical director
ID8	R&D Director
ID9	Automation supervisor
ID10	Servitization & Innovation manager
ID11	Head of the company
ID12	President
ID13	R&D - Manager Engineer

ID14	Italian sales manager
ID15	Italian sales manager
ID16	Innovation hub manager
ID17	IoT manager
ID18	Sales manager digital products and services
ID19	IT manager
ID20	Sales and Marketing director
ID21	Marketing Manager
ID22	Sales Manager

First of all, we must analyze the structure of the questionnaire. It was composed of 29 questions with different types of investigations: open questions, multiple choices, and rating scale questions. In the majority of these, was asked to evaluate a specific characteristic or event with a range going from 1 to 7 in which the sense attributed to every number was specified in the question and varies according to it. The questionnaire was administered in Italian.

The entire survey can be divided into six different areas of investigation proposed to obtain an overview of the current status of the company towards the PSS project.

The first one analyzes the current status of the firm with information about the size of the company, the current stage of servitization, its perceived importance in the business context, and the digital readiness.

The second part can be summarized as the one concerning the beginnings of the transition from product to service with questions about the trailblazers of this process and the key clients involved.

The third part concerns the set of technologies utilized for the PSS project while another part focused on the skills linked with the shift, the readiness of the company, and the actual response that the company has concerning the project.

Another section concentrated on the relationship with external suppliers and the ecosystem in which the company is operating. In the last part of the survey questions focused on the future of the firms and the desired achievements that the company wants to obtain in next years.

The questionnaire is reported both in Italian and English in the Annex. It is possible to consult it to read the list of the questions involved in the survey.

In this Chapter, two analyses are presented; the first one is a descriptive analysis of the obtained results while the second one is a QCA (Qualitative Comparative Analysis). *"QCA is a comparative case-oriented research approach and collection technique based on set theory and Boolean Algebra"*(Marx et al., 2014a) created by Charles C. Ragin in 1987 in his book "*The Comparative Method"*. The two easiest purposes of this method are to summarize data, describing cases in an easy-comprehensive way but also synthetically, and to check the coherence of a given set of conditions to produce a specific output. The descriptive analysis is developed with the purpose of better understanding the second one and presenting an overview of the results obtained in the survey. Further explanations are given below.

4.2. Descriptive Analysis

This part proposes the descriptive elaboration of the obtained results also to give a concrete basis for the QCA.

In *Table 3*, it is possible to analyze the field in which each respondent operates. The answers refer to question number 1 of the survey (please, refer to the Annex to read the entire questionnaire).

Table 3. The answer of the respondents about the sector of business.

BUSINESS SECTORS OF RESPONDENTS	
Painting machines	Design and production of compressors and compressed air dryers
Production of industrial refrigerators	Packaging machines and materials
Design/production/sale of machine tools	Mechatronic systems for packing and packaging
Designing and selling machines for industrial filtration	Automatic machines for wood and other materials processing
Automatic machines for packaging	Design and construction of systems for the automatic handling of materials with experience in synthetic wire reels
Machine tools for sheet metal working	Plants and machines for natural agglomerated and sintered stone and machines for the processing of metals and composites

Control and monitoring of air conditioning, refrigeration, and humidification systems	Design and production Industrial machines
Boilers, heat pumps, water heaters /HVAC	Foodservice equipment
Steel drawing lines	OEM converting lines
Stick packing machine (CS)	Manufacturing
Ice-cream Machinery	Pump

As previously mentioned, the questionnaire's respondents were chosen to have a high-level perspective of the PSS situation in Italian manufacturing firms. The answers obtained are consistent with this assumption.

One of the first questions regards the firm in which the respondent currently operates, the following graph visually represents the distribution of the responses divided into different categories

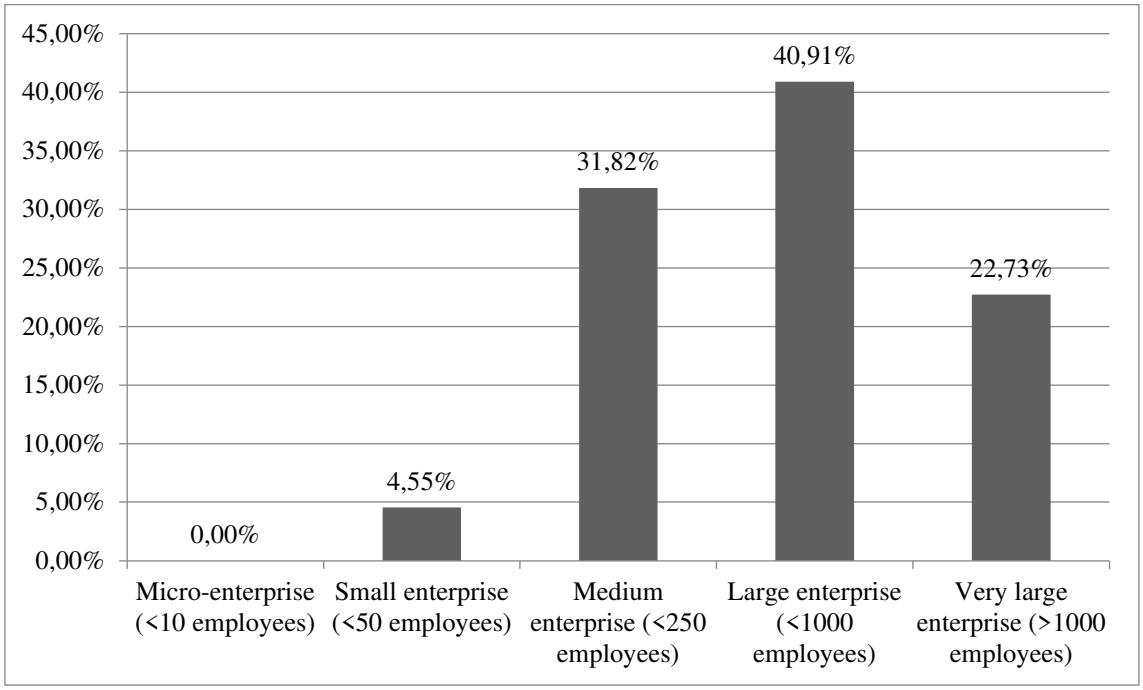


Figure 13. Dimension of the firm of the respondent

As we can see, there are no micro-firm involved in the survey (less than 10 employees), and most of the respondents were from a large firm with an employee range between 250 and 1000.

Furthermore, was asked also about the year in which the servitization project started and the responses were distributed from the year 2014 to 2021 with an average around 2016. The average duration of the project was equal to 5,32. There is also an outlier in this question, as we can see in the Table, that started the project in 2007.

Table 4. Duration of the PSS project of the respondents

Year	***n***	***%***	***Project duration (years)***
2007	1	5%	15
2014	2	9%	8
2015	3	14%	7
2016	2	9%	6
2017	3	14%	5
2018	7	32%	4
2019	3	14%	3
2021	1	5%	1

To concrete estimate the level of products of the firm was asked to the respondent the number of installed based products currently implemented. The answers vary a lot: with a minimum value equal to 1 and a maximum equal to 20.000. The average, in this case, is equal to 1830 and the median is equal to 94,5.

In addition, the respondents were questioned to answer about the current stage of servitization divided into early stage[9], introduction[10], development[11], or maturity[12]. The results are represented in the following table:

Table 5. The answer of the respondents about the current stage of the PSS project.

ANSWER CHOICES	*RESULTS*
Early stage	4,55%
Introduction	31,82%
Development	36,36%

[9] Early stage was defined as a situation in which the company has POC (Proof of Concept) or MVP (Minimum Viable Product)
[10] Introduction is described as a situation in which the company have a prototype not yet deployed or in use by a few customers
[11] Development is described as a situation in which the company we have refined the solutions and begun distribution and sales
[12] Maturity is described as a situation in which the company digital services have had pricing, revenue and market for at least one year

Maturity	27,27%

Few respondents were at an early stage of their project, but the rest of the results were almost equally distributed between the introduction, early stage, and maturity.

As previously mentioned, another part of the survey was focused on the investigation of the early stage of the servitization process. Accordingly, was asked to respond about the forerunner's role. In *Figure 14,* we can see how the highest stimulus to servitization in this sample was given by the management (36,36%) followed by the after-sales services (27,27%). The lowest result was obtained by Marketing and Sales (13,64%) and R&D and product development (13,64%).

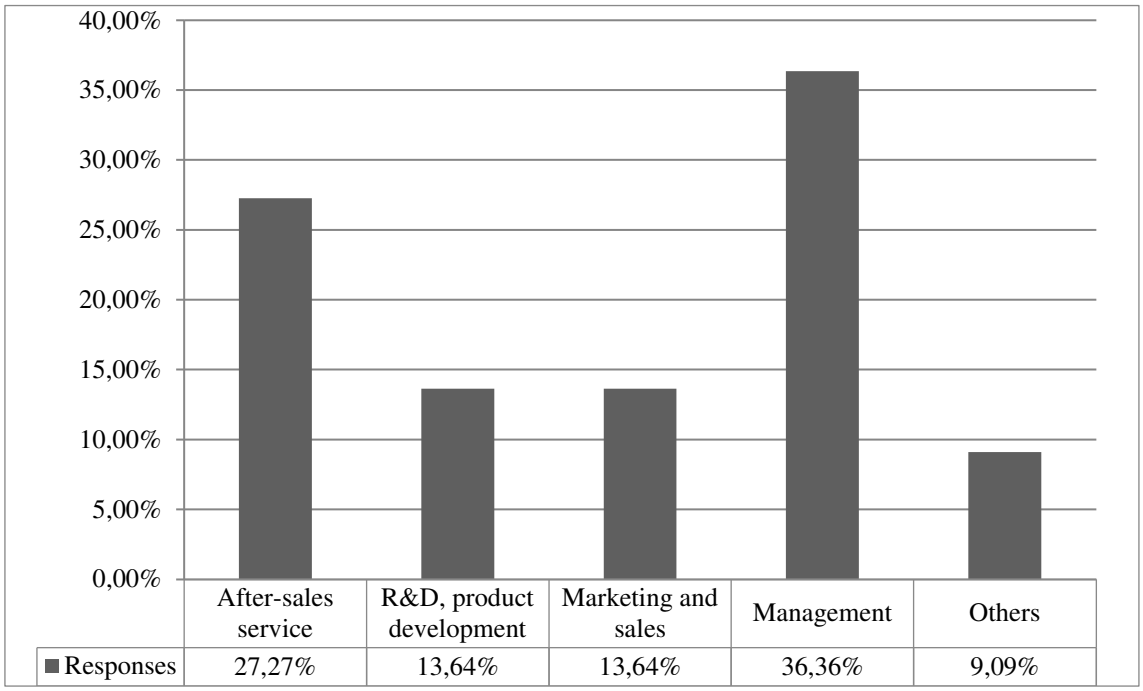


Figure 14. representation of responses of the ranking of a push towards the project

Another factor to which managers and directors were asked to respond was the key client role in the process.

First, there was a question about the presence of a key client or pilot client which helped in the transition process. The responses are reported in *Table 6*.

Table 6. Distribution of answers about the presence or absence of a key client

ANSWER CHOICES	*RESULTS*
Yes	68,18%
No	31,82%

As shown, most respondents were helped by a key client in the development of the service. Was also asked to rank the current relevance of the relationship with the client (from 1 to 7)[13]. The weighted average was equal to 3,95.

Another part of the survey focused on the actual service offering of the firm.

One important question was one about the perceived importance of the service in the competitive strategy of the firm. In question number 3 (please refer to the Annex) was asked to the respondents to rank this characteristic. The weighted average result is equal to 6. It means that the overall attention in the sample to servitization is high.

Fourteen over twenty firms ranked the service business as very or extremely important.

Table 7. Responses about perceived importance of service in the strategy

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Weighted average*
Perceived importance of services in the competitive strategy	0.00%	4.55%	0.00%	4.55%	22.73%	18.18%	50.00%	6.00

Different results were obtained concerning question number 4 (please refer to the Annex). The digital readiness of the company (i.e., ERP, MES, CRM, etc.) with a weighted average of 4,86 and a minimum, in this case, higher equal to 3. In addition, more than 25% of the firms ranked themselves as very or totally ready. None of the firms considered themselves as digitally totally unprepared.

[13] In the range 1 means not important anymore and 7 means extremely important

Table 8. Responses about perceived digital readiness in the company

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Weighted average*
Perceived digital readiness	0.00%	0.00%	9.09%	27.27%	36.36%	22.73%	4.55%	4.86

Continuing, a list of options was proposed with the chance to select more than one offer concerning services proposed to the customers. This set was composed of online documentation about the product, e-commerce for spare parts and materials, remote monitoring and web/digital application, remote monitoring with control room, technical helpdesk integrated with the remote monitoring, service intervention with AR, predictive maintenance, pay-per-use contracts, service contract linked with the usage and other. In *Figure 15,* we can view more than 80% of the respondents proposed to their customers' online documentation about the product (81,82%). In addition, both monitoring through web/digital applications and technical helpdesk integrated with remote monitoring obtained 77,27%. The less offered service in the survey were: service contracts based on results (13,64%) and pay-per-use contracts (4,55%).

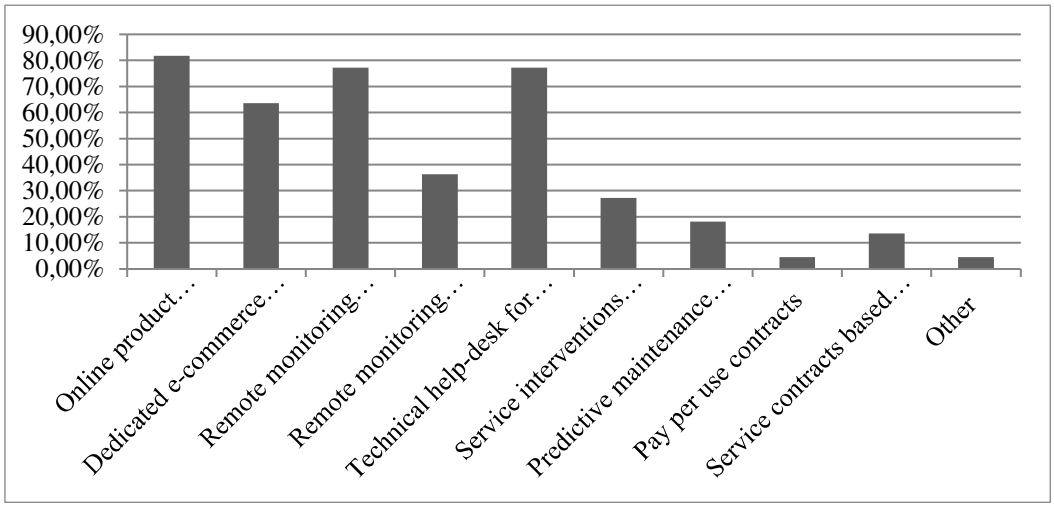


Figure 15. Distribution of respnses about the use of a certain technology in the PSS project

Moreover, concerning the level of customization, most of the respondents proposed a mostly standard service (with a ranking of 4,9 on the scale from 1 to 7). On the other hand, the customized service offering reached 3,27 for the strongly customized service and 3,65 for customizing on-demand. A significant part of the respondents disagrees with providing customized digital services.

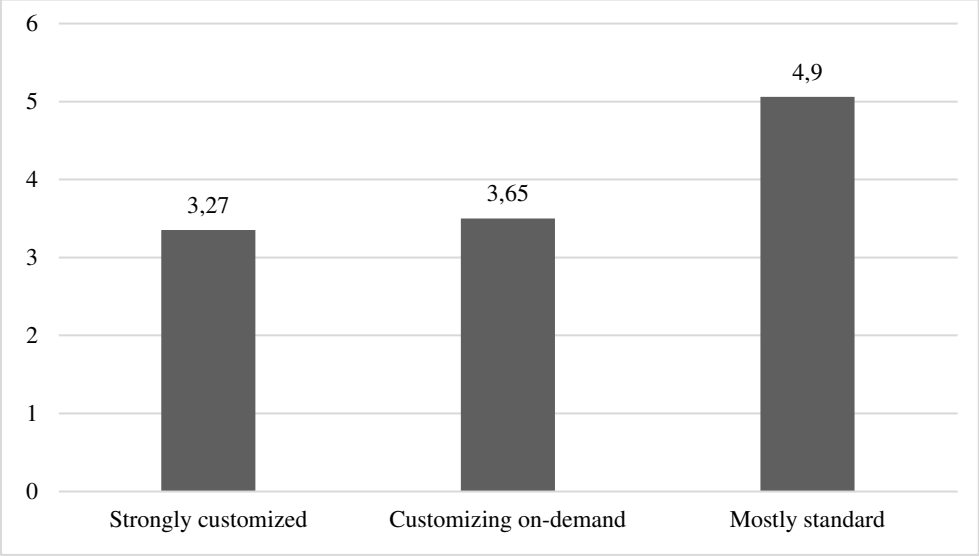


Figure 16. Ranking of the respondents of the level of customization of their services

Another important focus was the one about the type of services proposed and its appliance in different sectors. The following table shows the result of the respondents:

Table 9. Distribution of responses about the type of offered service

ANSWER CHOICES	*RESULTS*
Industry-specific[14]	50,00%
Cross-industry[15]	50,00%%
Not-specific[16]	0,00%

No imbalances were detected about the type of services proposed with balanced responses between industry-specific service and cross-industry service offerings. On the other hand, none of the respondents proposes to its customers' not-specific services.

[14] Industry-specific services were defined in the questionnaire as services suitable exclusively for the respondent's industry

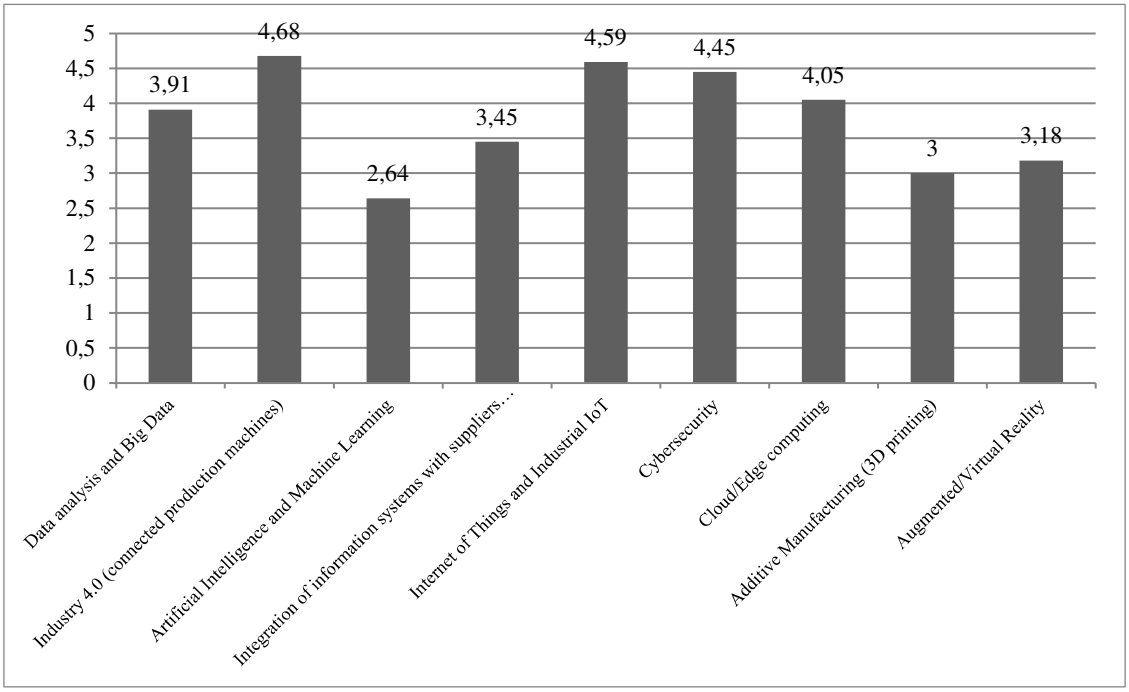
[15] Cross-industry specific services were defined in the questionnaire as services suitable for use in other sectors (even potentially)

[16] Not-specific services were defined in the questionnaire as services usable in all sectors with a focus on the solution)

In the following question, more details about the set of technologies used inside the company were asked: a list was proposed with a range from 1 (not used) to 7 (often used) of data Analysis and Big Data, Industry 4.0., AI, and Machine Learning

The weighted average of the results is presented in the Figure *17.*

From the graph, we can deduct that the set of technologies is enough homogenous in its usage with a similar medium average. The most used technologies are Industry 4.0., IoT and Cybersecurity. Instead, the least used technologies are Additive manufacturing, VR and AI.



About the business model was asked to respond to the following question: "*do you have a direct relationship with the final user of your service"*. The results are represented in the following table:

Table 10. Distribution of responses about the relationship with the final user

Answer CHOICES	*RESPONSES*
Yes (with most of them)	50,00%

Figure 17. Distribution of responses about the usage of the technologies inside of the firm

No (with almost none)	50,00%

As we can see the situation is equally distributed between these firms that have direct contact with the final user and the ones that do not.

Concerning the impact of services on different areas was asked the respondent to evaluate (from 1 to 7) the impact on the following areas: value creation, value proposition, value distribution, costs area, and revenues area. As we can see from *Figure 18* the impact on each area was evaluated on average with a value at minimum equal to 3,18 and maximum equal to 4,45. The highest impact was attributed to value proposition, while the lowest was given to impact on revenues.

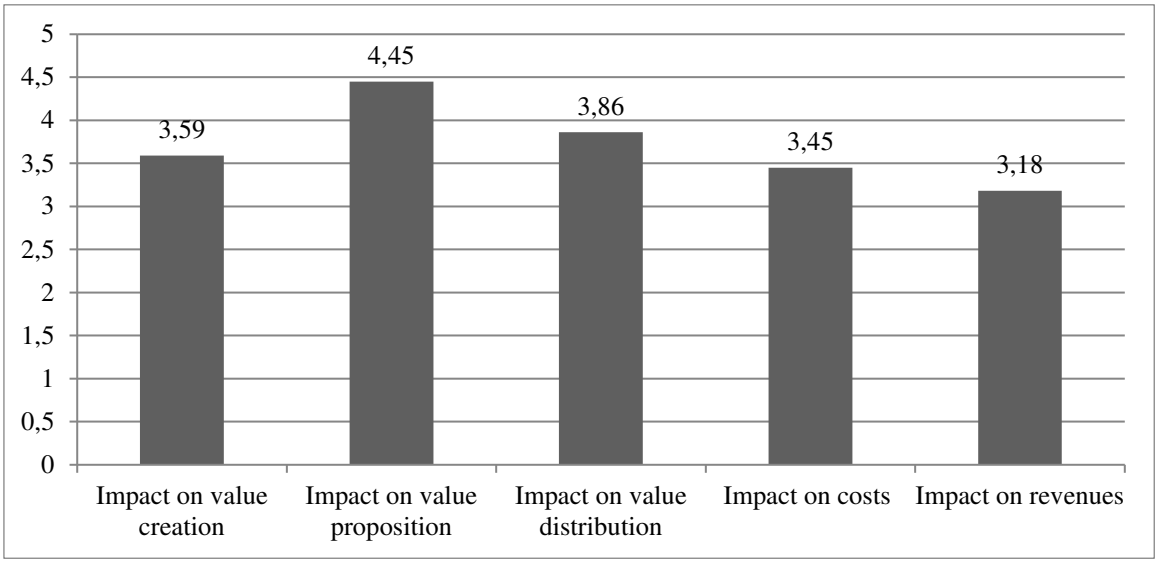


Figure 18. Distribution of responses about the impact on different value

The following part of the survey concentrates on people and their role inside the firm.

The first question was about the number of people involved in the project. The average number was 4,4 with an average of 2 people specifically hired for the project and almost 1 (on average) only occupied on the data analysis.

Moreover, the relevance of the contribution of internal competencies to the DS project is evaluated concerning different domains of contributions. Question number 19 (please refer to the Annex) asked to rank from 1 to 7 the use of internal competencies in the PSS. In the graph below (*Figure 19)* we can see that for all the fields the weighted average is in the range from 4,82 to 5,55. The most used are the ones concerning IoT devices and connectivity.

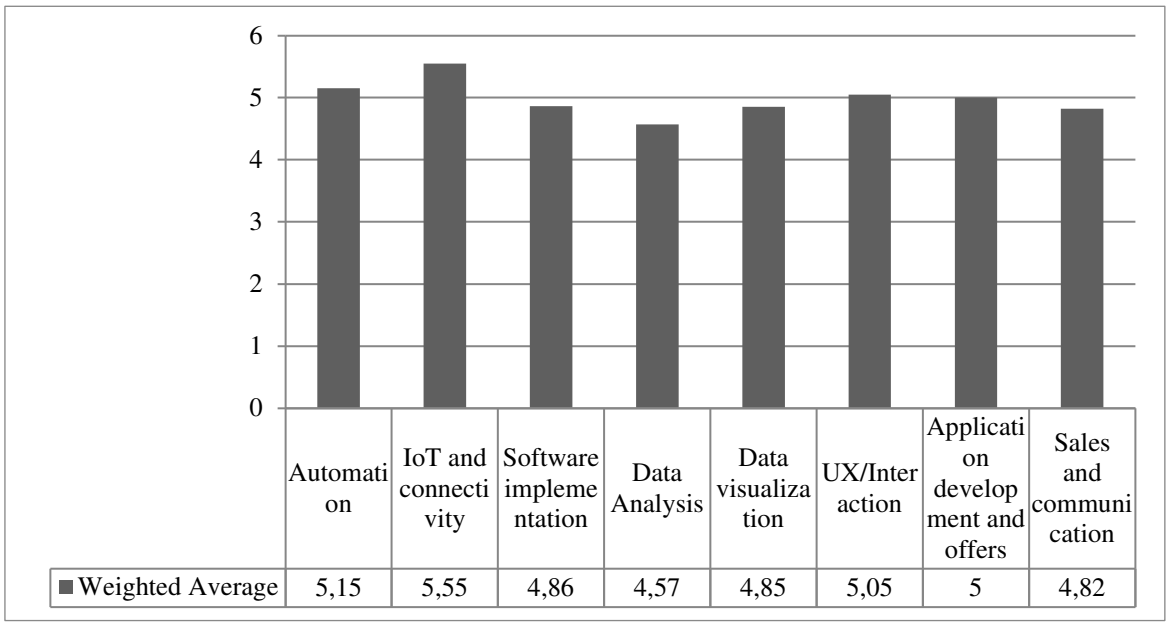


Figure 19. Response about the utilization of technologies inside the firm

In addition, question number 20 asked to evaluate the internal participation of competencies in the project, ranking it from 1 to 7[17].

The weighted average was equal to 4.3. It is interesting to notice that none of the respondents ranked it equal to a maximum value.

Table 11. Responses about perceived participation of internal competencies in the project

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Weighted average*
Perceived participation of internal competencies in the PSS project	4.55%	9.09%	22.75%	4.55%	31.82%	27.27%	0.00%	4.3

[17] In this question 1 means extremely lower on respect of internal potentiality and 7 means to the maximum extent possible

In question number 21 (please refer to the Annex), the respondents evaluated the response of the overall company in the digitalization process. Also, in this case, the range of responses went from 1 to 7[18]. The weighted average is equal to 4.50.

Table 12. Responses about perceived response in the project

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Weighted average*
Perceived response in the digitalization project	0.00%	13.64%	13.64%	22.73%	18.18%	22.73%	9.09%	4.50

In addition, was asked also the major area of resistance with the result reported in *Figure 20*. In the sample, the highest friction was given by the Sales and Marketing department (45,45%).

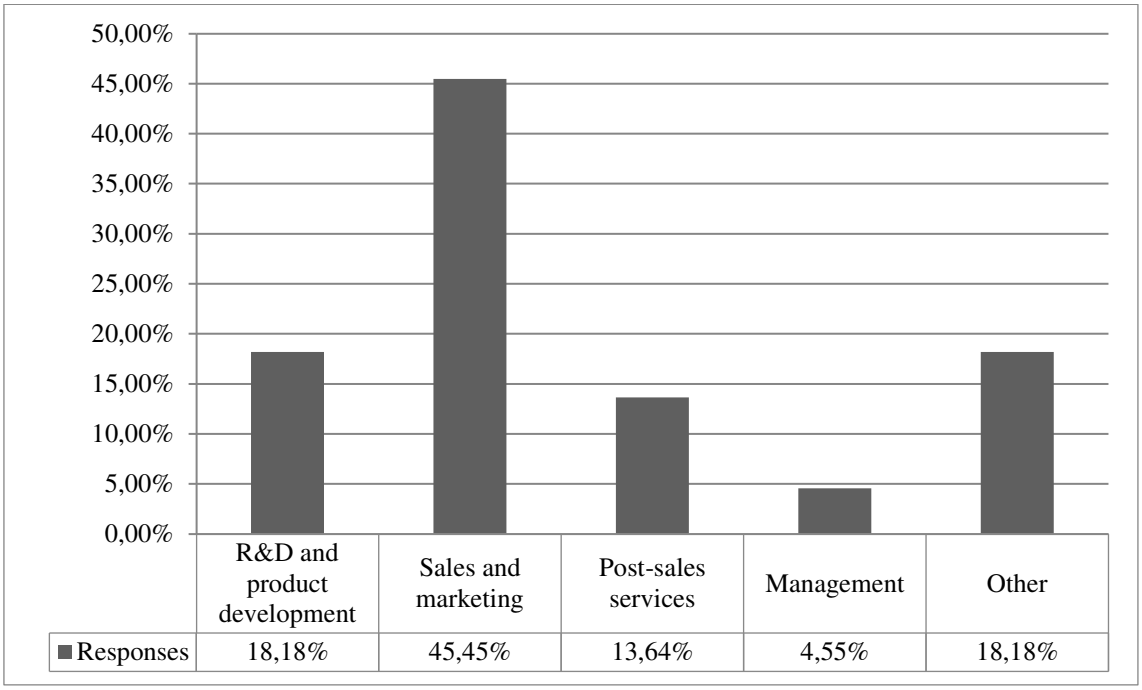


Figure 20. Distribution of the ranking of the respondent about friction in the project by different areas

[18] In this question 1 means negative response and low adaptation 7 positive response and maximal participation

Concerning the second to last part, the external relations in the servitization field were investigated.

Question number 23 asked to indicate the number of external relationships activated from scratch specifically for the project. The results are reported in the following list:

- 1 firm started 0 new external relationships (5%)
- 4 firms started 1 new external relationship (18%)
- 3 firms started 2 new external relationships (14%)
- 4 firms started 3 new external relationships (18%)
- 6 firms started 4 new external relationships (27%)
- 2 firms started 5 new external relationships (9%)
- 1 firm started 6 new external relationships (5%)
- 1 firm started 10 new external relationships (5%)

As we can see the number of relationships created only for the project was of a minimum of 0 and a maximum of 10. The average of the sample was equal to 3,27.

In the next question was investigated the number of these relationships that replaced and complemented existing relationships.

Table 13. Details about new external relationships

Answer Choices	*Total Number*	*% of total relations (72)*
Substitute existing relationships	5	7%
Support existing relationships	30	42%
New relationships that don't relate to existing ones	*37*	*51%*
Technology-connected (sofware, cloud, AR/AI, platforms)	48	67%
Linked with managerial and organizational services	6	8%
New relationships not related to technology or strategy	*18*	*25%*

As we can see, 7% of the relations substitute existing ones, which are little useful for DS. For the rest of new relationships, the relevance is almost equally divided into relations that support existing ones and new relations that don’t relate to them.

A vast majority of relations (67%) are related to technology and only a few (8%) to managerial and organizational subjects.

Lastly, was asked the role given to some specific characteristics in managing the external relationships related to digital services (question number 25). Also in this case was asked to evaluate with a value from 1 to 7[19] each of these factors.

	Weighted Average
Contractual regulation	4,36
Role of trust	4,95
Frequency of relationships (closeness)	4,9
Level of sharing of activities and decisions (adaptation)	4,73
Frequency of coordination meetings with external partners	4,14

The role of trust, closeness, and adaptation are near level 5, relatively more important than contractual regulations. Coordination meetings with external partners don't seem to be very important for the sample.

The position of the company in the value chain is investigated in the last part of the survey. In *Figure 21* a series of graphs about this topic of investigation is reported.

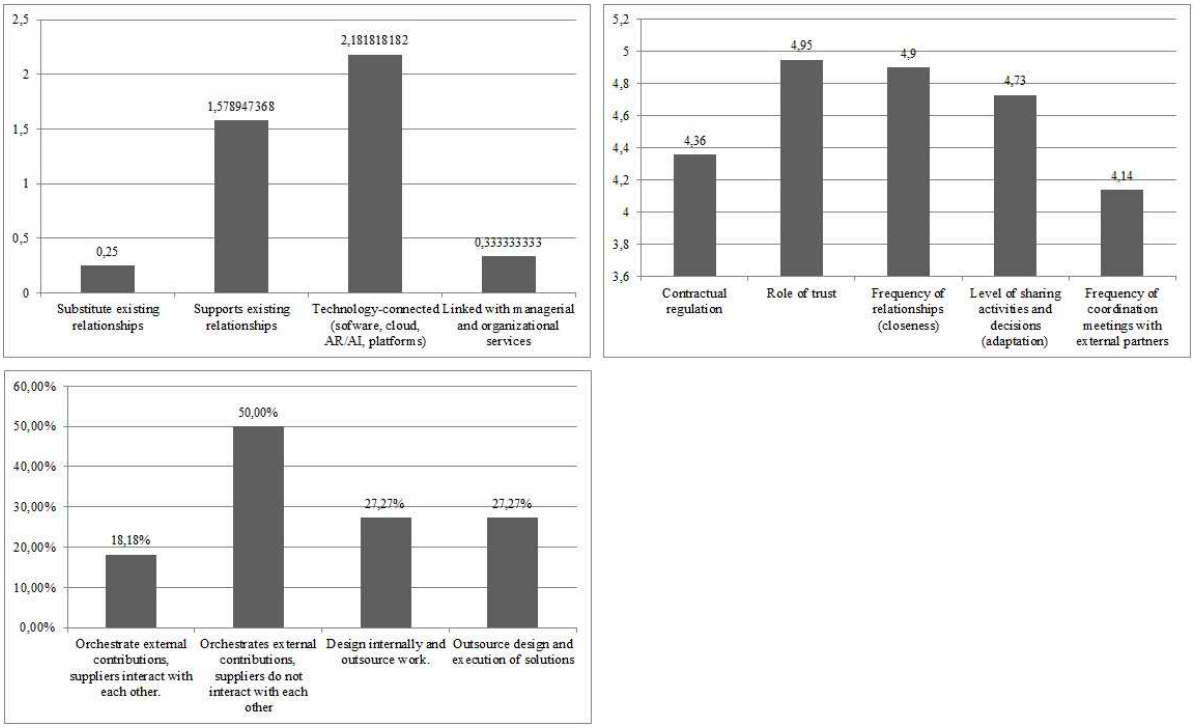


Figure 21 Graphs of results of average number of previously mentioned relationships (top-left), given importance to characteristics of this relationships (top-right), position in the supply chain (bottom-left)

[19] In this question 1 means not important at all and 7 means extremely important

At the top-left are represented the result of the values of the average number of previously mentioned relationships that: substitute existing relationships, supports existing relationships, are technology-connected (software, cloud, AR/AI, platforms), and are linked with managerial and organizational services. At the top right are also reported the weighted average of relevance given to some external factors in the managing of these relationships. Finally, the graph at the bottom-left shows the data concerning the position that the firm covers in those relationships.

Finally, concerning the last part, two questions about the future perspective of the business were presented. Also here, a range (from 1 to 7)[20] was suggested about: product, software, service, and communication. As we can see represented in *Figure 23* even if only slightly, the higher weighted average was attributed to the service (5,95). Communication is the less important but relevant (5).

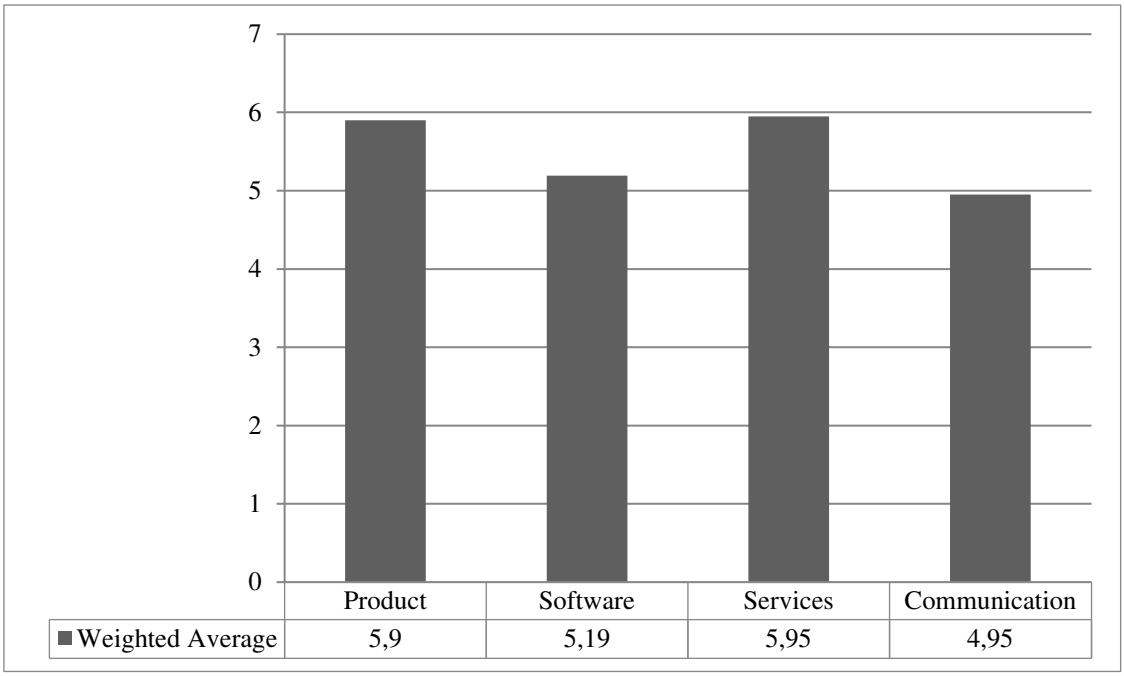


Figure 22.The importance attributed by the respondents to product, software, services, and communication

In conclusion, was asked about the desirable changes that they want to adopt in the future.

[20] In this question 1 means not at all and 7 means at all

Most of them answered that a partnership with specialized companies is the best option (72,73%) but at the same time 50% of the respondents want to internationalize some resources and activities. These results are reported in *Figure 24.*

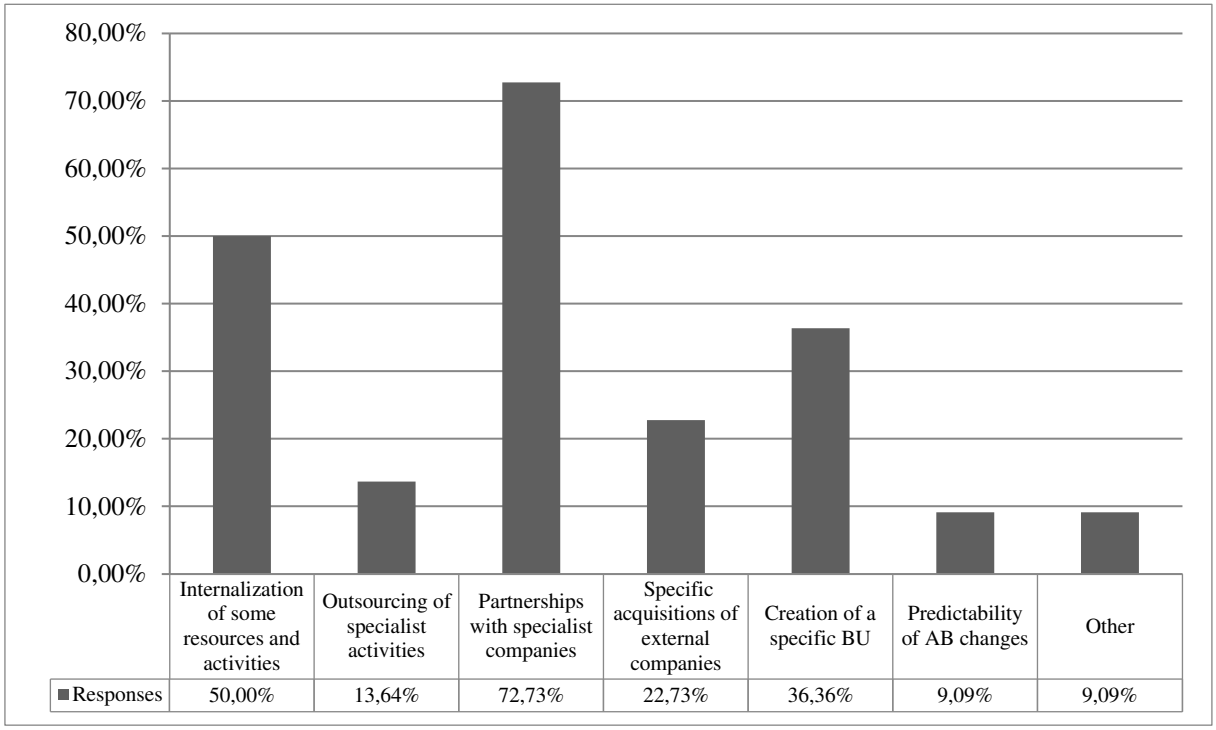


Figure 23. Distribution of ranking by the respondents about the future of the firm

4.3. Qualitative Comparative Analysis (QCA)

In this chapter, the goal is to understand which set of conditions can lead to a higher intensity of new external relationship through the usage of a Qualitative Comparative Analysis (QCA) and specifically a Crisp-set QCA (csQCA). The following analysis uses data from the survey and the deduction previously reported by the descriptive analysis in order to determine the thresholds of every condition.

In fact, the survey was developed according to this specific purpose. For instance, many of the involved questions use the Likert scale as a method of investigation that is known as good practice to develop QCA. In the following sub-sections, all the information necessary to develop this type of analysis are described.

In the first part the methodology, purposes, and precedent applications of this method are reported in order to obtain an overlook of what is the QCA, and which use is known as relevant in economic literature. Then, the set of the chosen condition is presented according to the previous literature and the thresholds for the definition of presence or absence of specific conditions are reported.

In the last two parts of this Chapter, results are presented. The discovered paths identified with the QCA will be assessed. In addition, an overlook of the companies involved in the responses will be reported using the obtained data from the survey following the descriptive analysis of the previous chapter. Last, the obtained model will be discussed.

4.3.1. Methodology, purpose, and other applications

"QCA is a comparative case-oriented research approach and collection of techniques based on set theory and Boolean algebra, which aims to combine some of the strengths of qualitative and quantitative research methods". (Marx et al., 2014b)

This technique was firstly developed in 1987 by Charles Ragin in his book "*The comparative Method"*. His work proposed to introduce a new logic of complexity reduction for social sciences. The logical bases of this method were firstly introduced by Hume (1758) and by J. S. Mill (1843).

The first important method which lays the foundations for the QCA is called the "method of agreement" and it is based on eliminating all similarities but one. Another important

technique, namely "method of difference", by contrast, find the absence of a common condition if all other are identical.

Both these methods were, in a sense, extreme in eliminating all other possibilities. QCA aimed to propose an alternative solution to these two to reduce this limitation.

There are two key advantages compared to the previously mentioned techniques. The first one is that different paths or combinations can produce the same outcome while the second one is that it allows asymmetries. It means that the presence and absence of the outcome can have different explanations (Sjödin et al., 2019).

In the case of categorical variables, QCA begins by listing and counting all types of cases which occur, where each type of case is defined by its unique combination of values of its independent and dependent variables. The basis lies in the fact that it is possible to observe empirical phenomena while controlling for contextual conditions (Ragin and Rihoux, 2008).

Ragin and Rihoux (2008) point out also that the key question is to understand which conditions (or combination of conditions) are necessary or sufficient to produce a certain outcome.

QCA can be used for at least five research purposes. The most basic use is the one in which this technique is used to summarize data. In addition, it may be useful to check the coherence of a given set of cases with some conditions against the detection of contradictions, allowing to identify of anomalies. The third use is to confirm or deny existing theories. Fourth, it is possible to assess new ideas on existing theories and finally, it can be used to develop also new theories.

After the publication of *The Comparative Method,* many researchers used it in specific subfields of political sociology as welfare states, revolutions, social movements, and industrial democracy. In the last decade, the use of this technique spread also to a wide variety of journals.

One important contribution in the economic field was given by Peer C. Fiss (2007) who demonstrated the value of QCA in studying organizational configurations and their applicability. It argued that research on organizational configuration was previously limited by a miss-match between theory and methods.

"*Set-theoretic methods offer a rigorous and nuanced way of assessing the complex ways in which causes combine to create outcomes, and these methods also show promise for a variety of research fields beyond the theory of organizational configurations.*" (Fiss, 2007)

Accordingly with the affirmation of Fiss (2007), from 1987 to 2014 the publication rates of QCA applications accelerated remarkably. The bibliographical COMPASSS database at www.compasss.org results that 39 journal articles that apply QCA were published both in 2011 and 2012, 60 in 2013, and 60 in 2014. Given the overall number of 397 empirical applications covered by the database in the period from Ragin's first book in 1987 until 2014, the evidence is that half of all journal articles used some variant of QCA have been published from 2010 to 2014. (Wagemann et al., 2016)

Konan Seny Kan et al. (2016) analyzed the use of QCA in the field of management with a critical and comprehensive review of all the uses of QCA in management until 2015. They demonstrated how QCA extends over an empirical method and how it offers a true formalization of qualitative analysis. (Seny Kan et al., 2016)

Overall, one important example of QCA's use is given by Sjodin et al. (2019). In their paper with the utilization of this method, they studied the ability to manufacture companies to offer advanced services and achieve superior financial performance. They answered this question revealing the relationship between advanced service provision, relational governance strategies, and financial performance of manufacturing firms.

Starting from a dataset of 50 Swedish service providers they used a configurational comparative method.

Another example of the QCA implementation was given by Albert et al. (Impact of digital transformation on the automotive industry (2021) in which they analyzed how digital technologies are modifying the automotive industry and disrupting the traditional business model in Spain. They covered connected and autonomous driving, mobility as a service, digital information sources in cars purchasing big data, and more. They found out that is fundamental to invest in adequate measures for implementing an effective digital transformation and to successfully gain higher profits, productivity, and competitiveness. (Llopis-Albert et al., 2021).

The previous descriptive analysis was necessary to initiate the Qualitative Comparative Analysis. As previously mentioned, the purpose is to identify if in the sample of analyzed Italian firms some conditions can describe a higher level of new external relationships accordingly with the theoretical framework.

As analyzed in the previous Chapter the survey focused on six areas of analysis: characteristics of the firm, conditions in the early stage of the project, actual service offering, people skills and characteristics, relationship with external suppliers, and future of the firm. The software used for the analysis was fsQCA 3.0.

4.3.2. Set conditions of the csQCA

This model was developed to investigate which are the paths that can contribute to a high level of new external relationships. The work is guided by the following overall research question: "which are the conditions of a company that, combined, can impact on the business model innovation in a PSS project?".

As previously explained the focus of the survey was on the product-service system of a sample of manufacturing companies in Italy.

The product-service system (PSS) refers to the output of the servitization process or a transformation journey of product-centered firms towards a product-service system (Frank, Mendes, et al., 2019b, Kowalkowski et al., 2017). This concept is strictly linked to business model innovations in manufacturing companies. Despite the increasing importance of this context, little attention has been given by academia to the description and formalization of PSS business models, guidelines, and tools. (Adrodegari et al., 2017). Nevertheless, from a business model perspective, PSS reconsiders the delivery of functional value to end-users through a mix of product and service. Value creation is more connected with service-value embedded in the product instead of sales and ownership The linkage, between PSS and business model innovation, lies in the description of how decision-makers are changing the business to perform in a sector in which the focus from one based ownership to one based access on the exchange of combined goods and services (França et al., 2017).

In this sense, system innovation is a big step for a company. Change is required in the internal and external organization, the company's mission, and in its way of thinking.

According to the literature previously analyzed, the creation of external relationships is relevant to BMI. The goal in this sense was to test the intensity of external relationships' activities in the manufacturing companies accordingly with the presence or absence of some specific conditions. The number of new external relationships created ad hoc for the project was chosen as the output of the analysis under this goal.

Moreover, the set of variables was chosen, according to the literature. These are listed in the following *Table 14* following the dimension identified by Dmitrijeva et. al (2020).

Table 14. Summary of the conditions chosen for the QCA

Organizational dimensions	**Themes**	**Assumption**	**Condition**
Maturity	Leadership, organizational culture, power, and politics, operational and strategic alignment, change acceptance	Employees 'skills facilitate the shift towards service focus (Gebauer, Fleisch, and Friedli 2005; Raja, Green, and Leiringer 2010)	High level of participation in the project of the available internal skills (Q20)
Capability	Service development capabilities, product-focused capabilities, learning capabilities, innovation capabilities, and complexity management	Availability of resources (e.g., a product sales force and distribution network or a field service organization (Ulaga and Reinartz2011), within or outside of the organization (Paiola et al.2013) facilitates the transformation	Large companies (Q2)
	Customers' requirements and tastes, economic and trading conditions, customer relationships,	Shifts in market orientation towards process-oriented services create a push for collaborative relationships (Bastl et al.2012; Oliva and Kallenberg2003; Oliva, Gebauer,and Brann2012)	High importance of services in the competitive strategy (Q3)

Market	legal requirements, market prudence Customers' requirements and tastes, economic and trading conditions, customer relationships, legal requirements, market prudence	Availability of consumer data facilitates servitization by creating new channels (Kowalkowski et al. 2017; Spring and Araujo 2016) and different types of service innovation (Coreynen, Matthyssens, and Van Bockhaven2017; Gago and Rubalcaba 2007).	End-user contact (Q7)
Technology	Information technology, product technology connectivity, sensor integration, analytics	IT facilitates servitization by improving the delivery of new services (Baines and Lightfoot 2014; Lightfoot, Baines, and Smart 2011; Story et al. 2017).	High digital readiness of the company (Q4)
Ecosystem	Supply chain control, open knowledge networks, collaboration practice, industry-level platforms, network competition	Innovation is always more linked with the presence of networks, relationships, and different forms of interactions with external players (Powell and Grodal, 2005)	High number of new external relationships created ad hoc for the PSS project (Q23)

High level of participation in the project of the available internal skills.
Question number 20 investigated the level of participation of the internal skills in the project through a self-assessment.
The assumption behind this chosen condition lies in the fact that employees' skills facilitate the shift towards service focus (Gebauer, Fleisch, and Friedli 2005; Raja, Green, and Leiringer 2010). Moreover, one of the important facts in the PSS BMI lies in the need to extend the product life cycle through maintenance and repair services. To achieve this goal, qualified employees must be present in the company. Organizational changes required by the concept will depend on the initial status of the company (Mont, 2014a).

Large companies. As we previously described, the first part of the survey was about the characteristics of the firm. According to the second question of the

survey (refer to the annex to specifically read the mentioned question), the variable Large Company was selected.

In this question was asked to the respondent to select the size of the company divided into micro-firm[21], small firm[22], medium-firm[23], large firm[24] , and very large firm[25] . The dimension of a company can be seen as a characteristic of organizational capability. It is defined as the "availability of resources (e.g. a product sales force) (Ulaga et al., 2011), within or outside of the organization that can facilitate the transformation. The goal is to identify if this condition can impact on the SBMI of the firm, based on the assumption identified by Ulaga and Reinartz (2011). In addition, if the company is not large enough to sell services and provide stable function as provision and maintenance it can represent a barrier to PSS BMI. (Mont, 2014a)

High importance of services in the competitive strategy. Question number 3 investigated the attributed importance of the service in the competitive strategy for the companies. This can be also seen as an indicator of the product-service system project focus in the firm. According with Calabrese, Levialdi et. al (2019) the degree of servitization can be measured by asking managers to evaluate how strongly they, the offering/development of additional services, usually on a Likert Scale.

End-user contact. To further investigate the market dimension was chosen question number 7. In fact, as previously mentioned this one captures the economic environment in which the manufacturer and its operations are embedded. In addition, a direct relationship with the final user firm can also be correlated with the ability to obtain consumer data. The availability of consumer data facilitates servitization by creating new channels (Kowalkowski et al. 2017;

[21] Micro-firm was defined in the questionnaire as a company with a number of employees lower than 10
[22] Small firm was defined in the questionnaire as a company with a number of employees lower than 50
[23] Medium firm was defined in the questionnaire as a company with a number of employees lower than 250
[24] Large firm was defined in the questionnaire as a company with a number of employees lower than 1000
[25] Very large firm was defined in the questionnaire as a company with a number of employees higher than 1000

Spring and Araujo2016) and different types of service innovation (Coreynen, Matthyssens, and Van Bockhaven2017; Gago and Rubalcaba2007).

High digital readiness of the company. The concept itself of the digital readiness of a company involves many aspects of a firm. From the evidence in the literature to assess the effective level of this characteristic inside a company, we can use four dimensions: process, monitoring and control, technology, and organization (de Carolis et al., 2017). Question number 4 asked to the respondent to evaluate the perceived level of the digital readiness of the company. This condition was also chosen to test the assumption that information technology increases the possibility for non-large companies to employ the PSS concept. (Mont, 2014b)

Moreover, a set of recommendations were defined in the work proposed by Mont (2014). First, the success of the PSS project depends on the creation of long-term relationships with customers. They can create both the demand for the product and can contribute to important information that can be useful in the product-service design. Also, some considerations under the dimension of the firms are proposed. Usually, large companies can outsource the serving parts more easily compared to SMEs. Moreover, selling services and providing stable functions require a higher involvement of employees in the provision and maintenance or investments in information technologies. This is easier for large companies that have higher resources. On the other hand, SMEs can have stricter contact with the end-user and acquire a useful advantage. In addition, the less complex organization involves usually shorter lines of communication, which helps to provide immediate feedback from the customers.

Accordingly, with the csQCA, each of these conditions must be transformed into a Boolean variable. Boolean algebra was developed in the mid-nineteenth century by George Boole. The Boolean principles used in the qualitative comparative analysis are quite simple. There are two conditions or states: true (or present) and false (or absent). These two states are represented in base 2: 1 indicates presence; 0 indicates absence. The typical Boolean-based comparative analysis addresses the presence/absence of conditions under which a certain outcome is obtained (that is, is true).

Each of the previously described conditions was transformed into a Boolean variable accordingly with the csQCA method. The following table (*Table 15*) summarizes the different thresholds that characterize the presence (value equal to 1) or absence (value equal to 0) of a specific condition.

Table 15. Thresholds for the presence or absence of each condition.

Variable	Description	Threshold	Attributed value	Question #
INTPART	Presence of a high level of participation in the project of the available internal skills	≥5	1	Q20
	Absence of a high level of participation in the project of the available internal skills	<5	0	
SIZELARGE	Presence of large companies	≥250	1	Q2
	Absence of large companies	<250	0	
SERVIMP	Presence of high importance of services in the competitive strategy	>6	1	Q3
	Absence of high importance of services in the competitive strategy	≤6	0	
DIGIREAD	Presence of high digital readiness of the company	>5	1	Q4
	Absence of high digital readiness of the company	≤5	0	
ENDUSER	Presence of direct relation with the end-user firm	YES	1	Q7
	Absence of direct relation with the end-user firm	NO	0	
NEWREL (OUTPUT)	Presence of a high number of new ad-hoc external relationships	≥ 4	1	Q23
	Absence of a high number of new ad-hoc external relationships	< 4	0	

The first condition defines the high level of participation in the project of the available internal skills. The threshold for this condition was set equal to the weighted average of the respondents rounded up. The value chosen for the presence of this condition is set

equal to or higher than 5. On the contrary, if the value is lower than 5 the condition is defined as absent.

Concerning the second condition, a large company was defined with a threshold of employees higher than 250. Under the result analyzed none of the respondents worked in a micro-firm company meaning that the size of the company can be divided into two categories: SME[26] and large firms[27]. In this case 250 signs the threshold between the presence of a large company and the absence of it.

The third condition concerned the level of perceived service importance in the strategy. For the examination of this variable, the threshold was set equal to 6, accordingly with the rounded up weighted average of the respondents in question number 3. With a value higher than 6 this condition is defined as present (equals to 1) while a value lower or equal to 6 defines the absence of the same.

The following condition, the high digital readiness of the company, is based on question number 4. It was asked to the respondents to evaluate the perceived digital readiness of the company. In this examination, the condition is present if the value is higher than 5 and absent if the value is equal or lower than 5. The threshold also here was chosen accordingly with the weighted average rounded up.

In question number 7, was asked if the company has a direct relationship with the end-user. In this qualitative response, the presence of the variable is defined if the answer of the participant is “Yes”. On the contrary, a “no” response corresponds to the absence of this condition.

The output of the model is defined according to question number 23 which asked to indicate the number of external relationships created ad hoc for the project.

It means that the last condition used was the one concerning the level of BMI created for the PSS. In our model, a value higher or equal to 4 represented a relevant business model innovation while a value lower than 4 means the absence of it. This threshold was set according to the weighted average of the respondents rounded up. A company with a number of new external relationships higher than 4 was defined as a company with a high

[26] Small and medium enterprises with a number of employees between 10 and 249
[27] Firms with a number of employees between 250 and more than 1000

number of external relationships and a relevant business model innovation. On the contrary, a value lower or equal to 4 represents the lack of a business model innovation.

4.3.3. Results

The first necessary step was to develop the database with the variables. A row for each answer to the questionnaire was created, inserting the Boolean values of the conditions identified before.

The typical result of the QCA consists of a logical statement that describes combinations of conditions that are sufficient for the outcome. A condition can be *necessary* and *sufficient*, only *necessary*, only *sufficient,* or neither *sufficient* nor *necessary*.

A cause is necessary and sufficient if it is the only cause that will produce a result, and it is singular (that is, not a combination of causes). A cause is sufficient but not necessary if it can produce the result, but it is not the only cause with that capacity. A cause is necessary but not sufficient if it can produce a result in combination with other causes and it occurs in all these combinations. Finally, a cause is neither necessary nor sufficient if it occurs only in a subset of the combinations of conditions that produce an outcome. In general, there are four categories of causes (formed from the crosstab of presence/absence of sufficiency versus presence/absence of necessity). (Thomas & Brunton, 2014).

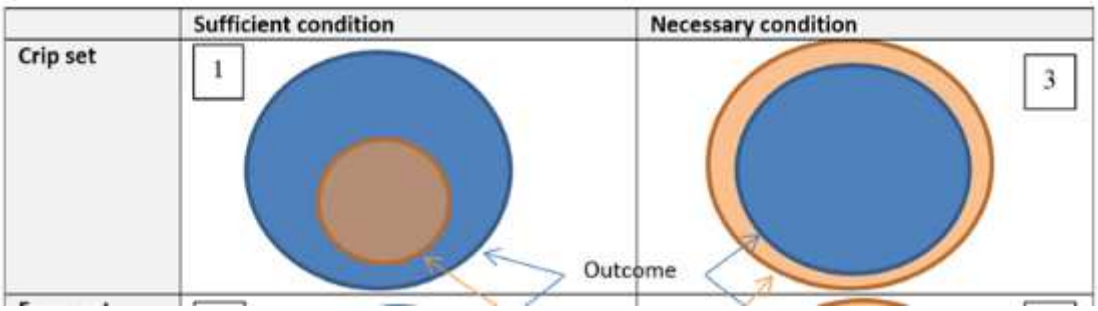


Figure 24. Representation of necessary and sufficient conditions. Source: Thomas and Brunton (2014)

The results of this analysis include measures of coverage and consistency for each solution term and solution as a whole. Consistency measures the degree to which solution terms and the solution as a whole are a subset of the outcome, while solution consistency measures the degree to which membership in the solution is a subset of membership in the outcome.

The first step when using csQCA is the analysis of necessary conditions. Conventionally, a condition or combination of conditions is "necessary" or "almost always necessary" if the consistency score exceeds the threshold of 0.8 (Sjödin et al., 2019).

Here consistency represents the degree to which the specific condition is a superset of the outcome while coverage represents the empirical relevance of a consistent superset.

A necessary condition X could be expressed in the formal notation:

$$X \leftarrow Y$$

The arrow just represents a logical implication that it says, wherever we find Y, we will also find X.

In *Table 16*, it is reported the result of the necessary condition analysis. The symbol (~) indicates the absence of the outcome/condition.

Table 16. Analysis of necessary conditions

Condition tested	**High number of new ad hoc external relationships**	
	Consistency	**Coverage**
INTPART	0.70	0.54
~ INTPART	0.30	0.33
SIZELARGE	0.60	0.50
~SIZELARGE	0.40	0.43
SERVIMP	0.60	0.54
~SERVIMP	0.40	0.36
DIGIREAD	0.30	0.50
~DIGIREAD	0.70	0.44
ENDUSER	0.50	0.45
~ ENDUSER	0.50	0.45

A condition is necessary if the consistency is higher than the threshold of 0.8. Since none of the variables reach this value none of them is a necessary condition to produce the outcome. In other words, none of the variables must be necessarily present to obtain a high number of external relationships in the sample.

In addition, digital readiness has a higher impact on the model when absent. On the contrary, the other variables have a higher impact on the output when present. The only variable that can be both present and absent is the contact with the end-user firm.

The consequent step is to perform the sufficiency analysis. The instrument that we must use to do so is the Truth Table. We need this to use Boolean algebra as a technique of qualitative comparison.

The output is shown in the *Figure 26.* The *number* column consists of the number of cases displaying the combination of conditions, while the *row consist.* column represents the proportion of cases in each truth table row that displays the outcome. Developing it, all the rows with less than 1 cases were delated to detect only situations in which a specific set of conditions was displayed in the sample. The outcome of a high number of new external relationships was defined by inserting a 1 for these cases in which the *raw consist* exceeded the threshold (0.75[28]) and 0 if it lower than the chosen value.

INTPART	SIZELARGE	SERVIMP	DIGREAD	ENDUSER	number	NEWREL	raw consist.	PRI consist.	SYM consist
1	1	1	0	0	2 (9%)	1	1	1	1
0	0	0	0	0	2 (18%)	0	0.5	0.5	0.5
1	1	1	1	0	2 (27%)	0	0.5	0.5	0.5
1	0	0	0	1	2 (36%)	0	0	0	0
1	1	0	0	0	1 (40%)	1	1	1	1
0	0	0	0	1	1 (45%)	1	1	1	1
0	0	1	0	1	1 (50%)	1	1	1	1
1	0	1	0	1	1 (54%)	1	1	1	1
1	1	0	1	1	1 (59%)	1	1	1	1
1	1	1	1	1	1 (63%)	1	1	1	1
1	0	0	0	0	1 (68%)	0	0	0	0
0	1	0	0	0	1 (72%)	0	0	0	0
0	1	1	0	0	1 (77%)	0	0	0	0
0	1	0	1	0	1 (81%)	0	0	0	0
1	1	0	0	1	1 (86%)	0	0	0	0
0	1	1	0	1	1 (90%)	0	0	0	0
1	1	1	0	1	1 (95%)	0	0	0	0
0	1	1	1	1	1 (100%)	0	0	0	0

Figure 25. Truth table obtained in the fsQCA 3.0. software

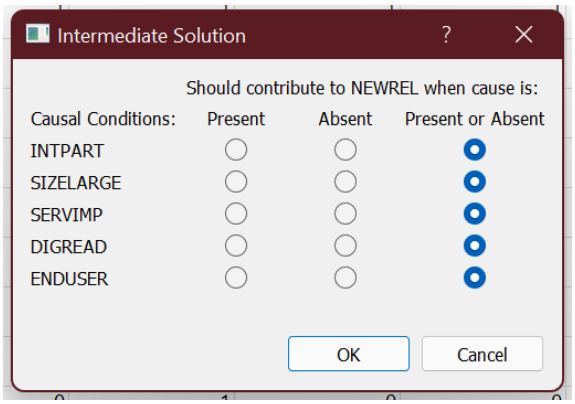
What is interesting to notice is that the situation in which all the conditions are present is not verified in any of the results but there are two cases in which all the conditions are

[28] Values below 0.75 usually indicate substantial inconsistency

absent. In this case, the output, a high number of external relationships, is absent (18% of cases).

Once the truth table is set up, the Standard Analyses can be performed.

Figure 27. Set of conditions and their definitions in the software



All the conditions should contribute to the output, high new external relationships, both when present or absent.

Following Ragin's (2008) recommendation, the intermediate solution is presented in which only remainders that are "easy" counterfactual cases are allowed to be incorporated into the solution. The result of the sufficiency analysis is presented in *Table 17*. Accordingly with the notation defined by Ragin and Fiss (2008) black circles (●) mean the presence of a factor while white circles (○) indicate its absence.

Table 17. Results of the standard analaysis in QCA

Conditions[29]	**PATHS FOR HIGH NEW EXTERNAL RELATIONSHIPS**			
	1	2	3	4
C1 (INTPART)	○	●		●
C2 (SIZELARGE)	○	●	○	●
C3 (SERVIMP)			●	
C4 (DIGIREAD)	○	○	○	●
C5 (ENDUSER)	●	○	●	●
Raw coverage	0.20	0.30	0.20	0.20
Unique coverage	0.10	0.30	0.10	0.20

[29] C1 high internal participation of internal skills in the projecy, C2 is large company, C3 high service importance in the competitive strategy, C4 is high digital readiness, C5 end-user contact

Consistency	1	1	1	1
Solution coverage	0.80			
Solution consistency	1			

The solution coverage of the model is equal to 0.80 meaning that 80% of the cases in which the output is present are represented from the following paths. The raw coverage of each path represents the number of cases covered by each of them.

In our research, the result of the intermediate solution represented expresses four possible alternative[30] paths to obtain a high number of external relationships:[31]

1. ~INTPART* ~SIZELARGE* ~DIGREAD* ENDUSER
2. INTPART* SIZELARGE* ~DIGREAD* ~ENDUSER
3. ~SIZLARGE* SERVIMP* ~DIGREAD *ENDUSER
4. INTPART* SIZELARGE* DIGREAD* ENDUSER

The raw coverage values range from 0.20 to 0.30. The highest raw coverage is attributed to the second path. It means that it represents 30% of the cases in which the output is present. The fact that also the unique coverage equals 0.3 means that these cases are also only explained by this combination of conditions.

4.3.4 Analyzing cases

To better understand the causal conjunction between a BMI and the presence of these paths described above it is necessary to further explore the companies involved. The aim is to use some qualitative and quantitative details from the survey and secondary data to support and confirm the model.

Table 18. Summary of the ID of respondents divided by path

PATH	CASES ID
PATH 1	ID3, ID22

[30] High new external relationships can be obtained by path number 1 OR path number 2 OR path number 3 OR path number 4

[31] * equals AND
~ means absent

PATH 2	ID9, ID10, ID17
PATH 3	ID4, ID22
PATH 4	ID14, ID19

1. Non-large with end-user contact companies

ID3 – This company operates in the painting machine industry, and it is a medium enterprise. There is a low to medium use of technologies within the company and IoT is the most used technology. The firm wants to focus on services in the future. They started in 2015 and are in the development phase. They offer highly customized and cross-industry services, and the biggest impact is on value proposition and value distribution. Concerning, people participating in the project, two persons are working exclusively on the project and one of them is only doing activities exclusively in data analysis. These two people were both hired ad hoc for the project. The skills used are fundamental to the automation and development of apps and offers. The generic response on the PSS project was evaluated as not very high. They have activated 4 ad hoc relationships for the project in the technology area (software, cloud, AR, etc.). Finally concerning the position in the supply chain, the company orchestrates external contributions and vendors do not interact with each other. In the future, they would like to internalize some activities.

ID22 – The firm operates in the OEM converting lines sector and it is a medium enterprise. Concerning technologies, there is an intense usage of Cybersecurity compared to others. The maximum focus is given to services and communication. They are at the early stage of the project and started in 2021. Their offering about service demonstrated that they produce mostly highly customized and cross-industry services. Since the recent start of the project, the impact is not high on any value area yet. Looking into people involved in the project, they have just one person involved ad hoc on the project. The response at the corporate level has not been good. Concerning external relationships, they have activated 4 for the project and most of them are related to the technological area. At this stage, they design internally

and outsource the work. In the future, they would like to internalize some activities and outsource specific ones.

BMI of medium-sized companies that have the maximum focus on services and specifically on highly personalized and cross-industry services. External relations have been activated for the project in the technology area and in the future, they would like to internalize some of the outsourced activities.

3. Non-large with a service focus companies

ID4 – This company is a medium enterprise that operates in the industrial refrigerators sector. The most utilized technology is Cloud.
The focus of the firm is mostly on service but at the same time on communication. They started in 2014 and are in the maturity stage. Services are personalized but not too much (4 out of 7) and industry specific. The highest impact there has been on the value distribution area. They don't have people working exclusively on the project. The firm have activated 10 new ad hoc relationships for the project, 2 of which have been added to existing relationships. The company orchestrates external contributions but would like to internalize some activities in the future.

ID22 – The firm operates in the OEM converting lines sector and it is a medium enterprise. Concerning technologies, there is an intense usage of Cybersecurity compared to others. The maximum focus is given to services and communication.
They are at the early stage of the project and started in 2021.
Their offering about service demonstrated that they produce mostly highly customized and cross-industry services. Since the recent start of the project, the impact is not high on any value area yet.
Looking into people involved in the project, they have just one person involved ad hoc on the project.
The response at the corporate level has not been good.
Concerning external relationships, they have activated 4 for the project and most of them are related to the technological area. At this stage, they design internally and outsource the work. In the future, they would like to internalize some activities and outsource specific ones.

BMI of medium-sized firms with a greater focus on services and communications. Both have limited if any resources allocated ad hoc to the project but would like to internalize some activities in the future.

2. Large with internal skills not digital ready companies

ID9 – This very large firm operates in the conditioning plant control and monitoring sector. The most used technologies are data analytics, big data, and AI. Their strategy focuses much more on the product than services. They started the project in 2018 and are in the development phase of the project. The services proposed are customizable on-demand and industry-specific services. Concerning the BM, the highest impact is the one on revenue. Five people were hired exclusively for the project over the 15 people allocated to it. The employees work in IoT area, data analytics and data visualization, app development, and offers. The project received a good response and there is high internal participation. Concerning the new external relationships created ad hoc for the project, only one replaced pre-existing relationships. The company designs products and services internally and then outsources them.

ID10 – This firm operates in the area of boilers heat pumps and water heaters, and it is a very large company. They use a lot IoT and AI and focus more on service. The project was started in 2019 and they define themselves in the maturity period of it. Services proposed to the customers are standard and industry specific. In addition, the biggest impact has been on value proposition and value distribution. Two persons are exclusively employed on the project. These are employed in device IoT, UX. The response in the project, also, in this case, was overall positive.
Concerning the four new relationships created, three have joined the pre-existing ones (two of them in the technology and software field and one on organization). The firm in the ecosystem plays an orchestrator role being that vendors do not interact with each other. In the future, they would like to internalize some activities.

ID17 - This very large firm works in the woodworking and other materials field. Concerning involved technologies in the project they use (but less than average)

Cloud. Their focus at this stage is on communication. Moreover, the project started in 2015 and is in the full project maturity phase. Proposed services are mostly standard but are cross-industry. The impact on value areas is low. There are ten people engaged for the project of which five are hired ad hoc. These oversee IoT, Software, data visualization, and UX. The response to the project has not been good.

Of the 5 new relationships, all of them were alongside pre-existing relationships in technology and software. The company designs internally and outsources the work and would like to create a specific BU in the future.

BMI of very large companies in already advanced stages of the project designing mostly standard services and using IoT. All of them are using external vendors and outsourcing some activities. Being large companies there are more internal skills, but this is not enough to internalize.

4. Large with internal skills and digital-ready companies

ID14 – This large company operates in machines and packaging materials. In the technological area, they use more IoT and all the data-related methods. They attach importance to products, services to communication but also software. The project began in 2017 and they are in the development phase. Services are highly customized and cross-industry. The highest impacts are on value proposition and revenue. Only two people work exclusively on the project and are in IoT, data visualization and UX, development, and sales. The overall response to the project has been good. They have created four external ad hoc relationships. Concerning the position in the supply chain, the company orchestrates external contributions but would like to internalize and create a specific BU in the future.

ID19 – This large enterprise operates in the natural stone machines sector. The use of data analytics, IoT, cybersecurity and AR is the most relevant. The major focus of the firm is on the product but is also high towards services. They started in 2015 and are in the development phase. The services offered are personalized and cross-industry and the biggest impact there has been on the value proposition.

There are eight people exclusively committed to the project of which five are

newly hired. Their role is linked with all the technologies mentioned in the survey. Finally, the number of ad hoc relationships activated is four. One of them joined the existing ones and one replaced the old ones. Here, too, the company orchestrates external contributions but also designs internally. In the future, they would like to internalize some activities.

BMI of large enterprises leveraging technologies related to IoT and data analytics more. The focus here is high on both products and services. Both are in the development phase and focus on customized and cross-industry services. The highest impact has been on the value proposition**.**

4.4. Discussion

The purpose of this analysis was to answer two specific research questions: "which are the conditions of a company that, combined, can impact the intensity of external relationships?" and "are these paths different for SMEs and large companies?". In order to respond the four paths identified through the QCA were divided accordingly with the size of the company.

This condition of discrimination was chosen to divide the paths according to the previously mentioned literature and research questions. This characteristic can, in fact, have an impact on many areas of the company resulting in different capabilities and abilities to implement different BM strategies. Accordingly, Dmitrijeva et al. (2020) affirmed that the capability dimension involves service development capabilities, product-focused capabilities, learning capabilities, innovation capabilities, and complexity management. In addition, recent work by Gebahuer, Paiola et al. (2021) addressed the importance of the dimension of the firm in explaining the interplay between digitization and servitization. These four paths are divided as follows.

NON-LARGE COMPANIES:

Path 1) non-large companies with a low level of internal participation and not digital-ready but with a contact with the end-user had more new external relationships

Path 3) non-large companies that value services as important in their strategy and have contact with the end-user but that are not sufficiently digital-ready, had more new external relationships

LARGE COMPANIES:

Path 2) Large companies with a high level of participation but that are not sufficiently digital-ready and do not have contact with the end-user had more new external relationships

Path 4) Large companies with a high level of internal participation that are digital-ready, and do have end-user contact, had more new external relationships

As we can see, if a company is non-large and is not digitally ready with non-high participation of internal skills in the project, it is necessary to have a direct relationship with the end-user firm. This is the case also in which high importance is given to the services in the competitive strategy. If we look at the paths of large companies, we can see that are two alternative paths. The first one (2) in which the company is not digital-ready but also has no direct relationship with the end-user, while the second one in which both these characteristics are present. Moreover, in both cases, a high level of participation of internal skills in the project is needed.

In the below table some basic information are presented accordingly with the results obtained by the QCA and the underline assumptions previously analyzed.

Table 19. Summary of assumptions, conditions and ID of respondents

Organizational dimensions	**Themes**	**Assumption**	**Condition**	**Path**	**ID of respondents**
Maturity	Leadership, organizational culture, power, and politics, operational and strategic alignment, change acceptance	Employees 'skills facilitate the shift towards service focus (Gebauer, Fleisch, and Friedli 2005; Raja, Green, and Leiringer 2010)	High level of participation in the project of the available internal skills (Q20)	**2, 4**	**ID9, ID10, ID17, ID14, ID19**
Capability	Service development capabilities, product-focused capabilities, learning capabilities,	Availability of resources (e.g., a product sales force and distribution network or a field service organization (Ulaga and	Large companies (Q2)	**2, 4**	**ID9, ID10, ID17, ID14, ID19**

	innovation capabilities, and complexity management	Reinartz2011), within or outside of the organization (Paiola et al.2013) facilitates the transformation			
	Customers' requirements and tastes, economic and trading conditions, customer relationships, legal requirements, market prudence	Shifts in market orientation towards process-oriented services create a push for collaborative relationships (Bastl et al.2012; Oliva and Kallenberg2003; Oliva, Gebauer,and Brann2012)	High importance of services in the competitive strategy (Q3)	**3**	**ID4, ID22**
Market	Customers' requirements and tastes, economic and trading conditions, customer relationships, legal requirements, market prudence	Availability of consumer data facilitates servitization by creating new channels (Kowalkowski et al. 2017; Spring and Araujo2016) and different types of service innovation (Coreynen, Matthyssens, and Van Bockhaven2017)	End-user contact (Q7)	**1, 3, 4**	**ID3, ID22, ID4, ID14, 1D19**
Technology	Information technology, product technology connectivity, sensor integration, analytics	IT facilitates servitization by improving the delivery of new services (e.g., reaction speed for a breakdown event) (Baines and	High digital readiness of the company (Q4)	**4**	**ID14, 1D19**

	Lightfoot2014; Lightfoot, Baines, and Smart2011; Story et al.2017).

To have a more precise overview of the previously described models, these are also summarized in the graph below (*Figure 29).*[32]

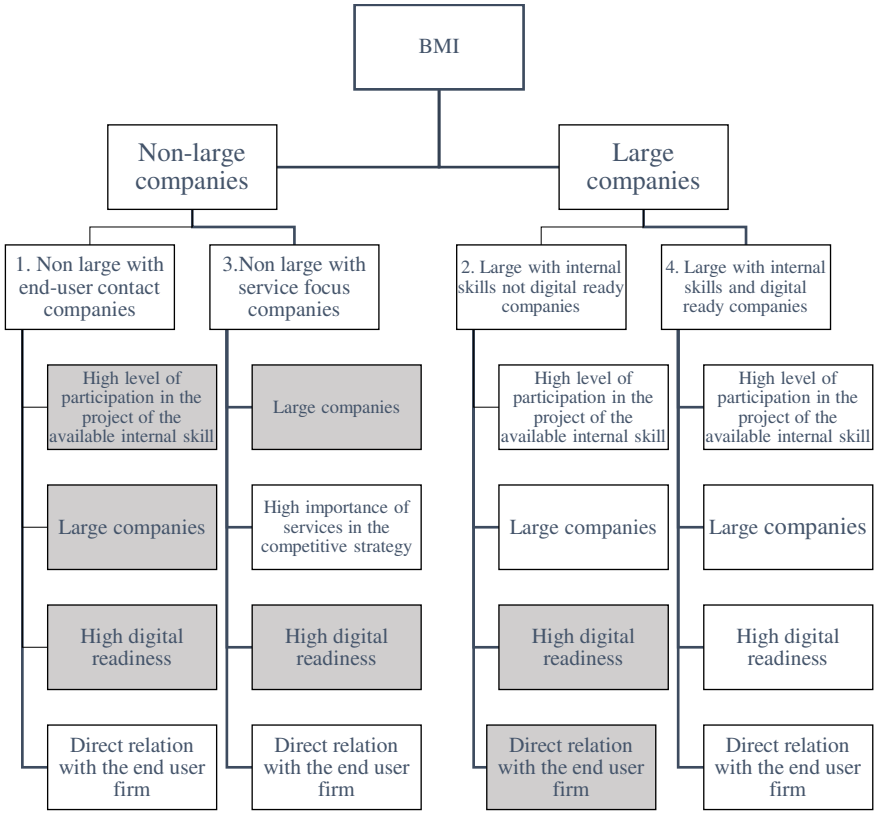


Figure 28. Graph summary of the result of the QCA

This part of the work aims to singly analyze each of these conditions and the impact that these have on the discovered paths also using the survey-related data and the secondary data. This is necessary to propose a more complete overview of the involved firms.

As previously mentioned, one of the most important factors in the model is the dimension of the firm. Two over four paths have the presence of this condition: path number 2 and path number 4. The large dimension of the company can impact the

[32] Grey squares represent the absence of the cited condition in the specific path

ability to design and sell stable function that requires personnel involved in the project. In addition, large companies can outsource some part of their activities thanks to their dimension. Large companies are involved in ID9, ID10, ID17, ID14, ID19.
These companies are large and very large firms operating in the control and monitoring of air conditioning systems, manufacturing of boilers, heat pumps and water heaters, woodworking and other materials, packing machines and materials, and machinery for natural stone working. On the other hand, we have two paths of non-large companies involving ID3, ID22 and ID4. These three companies are medium enterprises operating in OEM line converting, in the painting machine industry and in the refrigerators industry. Being that this condition was chosen to divide the paths, considerations about these characteristics must be made jointly with other conditions.

Another assumption was that employees' skills facilitate the transformation towards service focus BM. As presented in the graph, we can see that the high level of participation of internal skills in the project is present in path number 2 and path number 4. Looking at the involved paths in which this condition is present we can identify five answers: ID9, ID10, ID17, ID14, ID19. The companies involved in these paths and, specifically that have this assumption, are large and very large companies that are in advanced stages of the PSS or in the developing phase. The average starting date of the project for the involved company was 2017, four years ago. It may suggest that these companies had more time compared to others to develop and build these competencies internally and that are useful in developing PSS. On the other hand, this condition is absent in path number 1, probably because it involves two medium companies that have lower capabilities in terms of human capitals compared to large and very large companies.

Continuing, in the maturity dimension, we have two conditions.

The first one is the high importance of service in the competitive strategy of the firm. The presence of this variable is relevant only in path number 3. The responses involved in this path are ID4 and ID22. These two companies are SMEs with a higher focus on service compared to others. What is interesting to notice is that in the future both companies will focus on communication and not only on services.

The other condition involved in the maturity dimension is the contact with the end-user. This condition was present in paths 1, 3, and 4, involving responses ID3, ID22, ID4, ID14, 1D19. the presence of a direct relationship with the end-user is present in both large and non-large paths. It seems to confirm the assumption that SBMI is lead also by the customer willingness to outsource maintenance and services (Jovanovic, Engwall, and Jerbrant2016; Kowalkowski 2011) and integrate customer resources into value creation (Ng et al.2012). The answers obtained by these respondents seem to suggest that services offered to customers are linked with the fact that they decided to outsource maintenance and services. In addition, this characteristic was absent only in one path, path number 3, which involves large companies. It may suggest that in presence of very large firms the end-user contact is not necessary being that for this company is possible to outsource some activities related with the end-user relationships. This is assumption is made under the fact that the three firms involved (ID9, ID10 and ID17) are very large firms which are orchestrator of external contributions or firms that just design solutions that are then developed outside.

Finally, we have digital readiness. This characteristic is more frequent in paths as non-present. The path in which this condition is present is path number 4. It involves ID14 and ID19. Both these firms exploit IoT technologies in their business model with a high focus both on product and service. What is interesting to notice is that they focus more on cross-industry and customized services with a high impact on the value proposition. The identified paths seem to suggest that a high digital readiness must be in most cases absent to obtain more new external relationships ad hoc with the project. To investigate this hypothesis an overlook on the type of new external relationship created in necessary for ID involved in set number 1, 2, and 3. These responses are the ones from ID3, ID4, ID9, ID10, ID17, ID22.

Question number 24 asked to define how many of the created relationships were linked with the technology (software, cloud, AR, AI etc.). *Table 20* is reported below to summarize data according to these two questions.

Table 20. Details about external relationships

RESPONDENT ID	NUMBER OF EXTERNAL REL.	NUMBER OF THOSE REL. RELATED WITH TECHNOLOGIES	%
ID3	4	4	100%
ID4	10	4	40%
ID9	6	2	33%
ID10	4	2	50%
ID17	5	5	100%
ID22	4	3	75%

As we can see from the table at minimum 2 of the created relationships were established in the field of technologies. Moreover, for ID3 and ID17 all the relationships created ad hoc for the project were linked with technologies. All considerations about this topic seems to be consistent with the concept of digital servitization and external relationships also analyzed in previous chapters.

Conclusions and implications

The proposed work followed multiple purposes that were summarized in this final Chapter.

First of all, an overlook of the challenges of modern industries was proposed. Two of the most relevant phenomena affecting the manufacturing sector were described accordingly with the disposable literature. In the first part, these two components were presented singularly according to the papers currently available.
Despite this fact, industry 4.0. and servitization are often blended in the firm context. For this reason, some conceptualization of how these concepts interact were presented to obtain a more "real" and empirical relevant overview of these two phenomena.

In the second chapter, a more in-deep analysis was presented concerning the set of technologies that populate the manufacturing sector nowadays also accordingly with Industry 4.0. This was important to better understand how these technologies work and also which are the possible advantages that a company can obtain using them in their business model.
In the third chapter is reported a theoretical background useful for the model successively developed. The service business model innovation was first introduced through an explanation of those factors, internal and external, able to impact the output of the servitization process. Then, different definitions were proposed of business model and, more precisely, of service business model. The concept of product-service system (PSS) was introduced and linked with the servitization process.
Finally, according to the literature, the impact of external relationships on business model innovation was presented also in the digital servitization concept.

The central chapter proposed the analyses of a survey managed in collaboration with the Digital Lab of the University of Padua. The questionnaire, composed of 29 questions, was administered to 22 high-level managers to have an overview of the business situation concerning the PSS project in which they are involved. The structure and characteristics of this survey were defined in order to use it in the csQCA.

A first descriptive analysis was reported examining the obtained answers of the sample, concentrating on the most relevant questions, and presenting an overview of the involved firms from different points of view. The past, current, and future of the PSS were investigated in many fields going from people involvement to companies' capabilities and characteristics.

The second part of the chapter proposed to test some theoretical assumptions and develop a model to investigate which conditions can have an impact on the service business model innovation of these companies. More specifically the aim was to examine which set of conditions, combined, can impact the intensity of new external relationships created for the PSS project. Additionally, was important to understand if the paths identified were the same between large and non-large companies.
For this reason, a qualitative comparative method and, more specifically, a crisp-set QCA was used. Conditions of the model were defined accordingly with theoretical assumptions and the threshold are presented under the previous descriptive analysis of the obtained results. Using software (fsQCA 3.0.) data were investigated and elaborated.
The output of the csQCA is a model composed of four alternative paths. All of them can lead to a high level of new ad hoc external relationships in the PSS field. Accordingly with the theory proposed, the output of the model can be seen as the achievement of relevant BMI.
The presence or absence of specific conditions in the defined paths seems to confirm previous literature results. It also confirmed the fact that the considerations made in the work by Dmitrijeva et al. (2020) for small and medium enterprises can be, in some cases, extended to large and very large companies.

The participation of internal skills in the project condition seems to facilitate the transformation through SBMI to obtain the high intensity of external relationships. As underlined by the assumption, employees' skills facilitate transformation towards service focus BM. In the paper, by Dmitrijieva et al. (2020) the expansion phase is linked to the development of service offerings and delivery mechanisms to streamline service value generation. This step is strictly linked with systematic experimentation, which is dependent on the manufacturer's ability to retain skilled staff and leaders inside the firm. This characteristic seems to be confirmed in our analysis in which companies involved in

this path are yet in the developing or advanced stages of the project with a high level of internal participation of skills.

To what concern servitization, and more specifically, the attributed high importance of service in the competitive strategy, the presence of this condition, to obtain a high number of new ad hoc external relationships, seems to confirm the fact that shifts in market orientation towards process-oriented services create a push for collaborative relationships (Bastl et al.2012; Oliva and Kallenberg 2003; Oliva, Gebauer and Brann, 2012).

In the context of end-user contact, three paths over four presented this condition. This can be explained by the fact that customer willingness to outsource services can impact SBMI. Each of the companies involved in these paths proposed at least one service in the monitoring sector (i.e., remote monitoring and web/digital application or remote monitoring with control room). Moreover, the fact that these companies had contact with the end-user seems to follow the recommendation proposed by Mont (2014). In this work was affirmed that contact with the end-user not only creates a demand for certain products but can also contribute with relevant information to be used in the product-service design, implying a positive impact on the PSS BMI and a higher intensity of external relationships for the project.

One of the most interesting aspects of the identified paths was the presence or absence of a high level of digital readiness inside the firms. Accordingly with one of the most interesting results in the paper by Dmitrijeva et al. (2020), technologies are defined only in one specific stage, the engagement stage. In this second stage, the manufacturer captures the systematic evaluation and communication of the servitization business potential.

In the developed model this condition is present only in one path. The companies' responses involved in it seem to correspond with some of the characteristics proposed by the model in the paper by Dmitrijeva et al. (2020). For example, the fact that in this phase customers drive the demand. In both the responses involved the companies affirm that they offer customized service to the clients. Moreover, the overall response in the project for these firms was positive (6 over 7 in both cases) accordingly with the characteristic of "enthusiasm from the internal teams" cited in the Dmitrijeva et al.'s work.

Finally, the absence of high digital readiness in majority of the paths, was explained by the fact that usually external relationships ad hoc for the project are initiated precisely to fill a technological gap in the company. These answers seem to confirm the fact that the external relationships may be linked with the lack of internal digital preparation.
This concept is also reported in many works of literature. The complex nature of the new market implies the difficulty or impossibility to provide a service to the customers with an end-to-end solution on their own. The need in this context is to sustain viable alliances and to create a value network with the right partners (Pagani & Pardo, 2017).
This is the natural consequence of a situation in which products and services are increasingly embedding digital technologies (Pigneur, 2000). Strategies involving digital business are strictly linked with the need to coordinate across firms in the product, process, and service domains and develop a complex ecosystem for innovation (Iansiti & Lakhani, 2014). Additionally, some of the respondents reported that they frequently outsource activities and use external vendors. This can be better represented by path number 2 in which the large company is not digital-ready and does not have an end-user direct contact.

Finally, many recommendations reported in the work developed by Mont (2014) about how to implement a PSS BMI seems to be confirmed in our sample demonstrating that these considerations made for Swedish firms are also confirmed in Italian manufacturing companies. First, the fact that customers can create both the demand for the product and can contribute to important information in product-service development seems to be consistent with the proposed model. The presence of end-user contact is a contributing factor in three over four paths.
Also, concerning the dimension of the firm, was tested that SMEs can have stricter contact with the end-user and acquire useful advantages. On the other hand, large companies seem to outsource more easily but also can provide stable functions compared to SMEs.

The presented results respond to the research question defining which are the conditions of a company that, combined, can impact the intensity of external relationships and more generally on SBMI. Precedent empirical results of the literature were tested and confirmed in this work for a sample of manufacturing Italian firms. In addition, a broader

context of analysis was proposed involving many relevant factors in digitalization, servitization and industry 4.0. linking this concept with business model innovation and external relationships.
In addition, the presence or absence of these conditions in different paths also focuses attention on the fact that different combinations can lead to the same high intensity in new external relationships accordingly also with the individual capabilities of the firm.

To conclude the analysis is also necessary to define and analyze which are the limits in this evaluation. The first issue is the one linked with the subjectivity of the respondents. The model is based on the responses of some representatives of the firm involved. Also, in this sense, a certain level of distortion of perception can impact the results being that often the questions refer to self-assessments.

Concerning the elaboration of this model, another limit is linked with the definition of SBMI. As we mentioned in previous chapters the very definition of this concept is not univocal. In this sense was chosen the one which link PSS BMI with the number of new ad hoc external relationships. The absence of a unique and shared method to measure this concept can be seen as a big limitation in the development of this analysis. In fact, choosing only one definition to obtain the output of the model is not enough to effectively represent the situation and the complexity of this phenomenon. The modification of the chosen definition can substantially change the outcome of this work.

The same consideration can be mode with every condition chosen based on an empirical definition. For example, the size of the company or the high digital readiness variable.

The most important limits are for this reason linked with the QCA itself. Many researchers studied the issue linked with this type of analysis in political science (Clarke, 2020).

The selection of cases, conditions, and indicators have a strong impact on the output of the analysis. It means that a degree of subjectivity is always present in conducting this type of research. Another implicit limit is represented by the number of cases analyzed that must be small to use this method of research.

In addition, the use of Boolean variables in affirming the presence or absence of certain conditions is also a limit per sè. This problem can be divided into three main restrictions. (Clarke, 2020). The first one is that Boolean algebra restricts what it is possible to describe

and know about groups of characteristics and how they interact. Secondly, Boolean algebra is the model for propositional logic[33] that seems to be weak to capture modern social science theories. Lastly, necessity and sufficient conditions are only a restricted part of possible causations.

Moreover, also in this situation, the Boolean algebra leads to the need to identify certain thresholds that frequently in our analysis are represented by average values obtained in the survey. In this sense, the sample of firms chosen strongly influences the outcome of the analysis.

To reduce the issue correlated with this model some guidelines can be followed before, during, and after the analysis (Schneider & Wagemann, 2010).

As explained in the paper by Schneider and Wagemann this method must be used only for the following aims:

- Summarize data
- Check coherence between data and subset relations
- Test existing hypotheses and theories
- Overview quickly the basic assumptions of the analysis
- Develop new theoretical arguments

In this work, the aim was to test existing hypotheses and theories concerning Italian manufacturing firms keeping a moderate number of conditions and to develop a new theoretical argument. To reduce subjectivity this work proposes tested assumptions based on previous empirical results.

This work developed a model composed of four paths, divided accordingly with one of the conditions involved that is the large size of the company. Findings are summarised in this last paragraph.

Two paths were identified concerning non-large companies and the other two concerning large companies. This differentiation was chosen to respond also to one of the research

[33] Propositional logic is a formal language with a simple syntactic structure, basically based on elementary propositions and true-type logic connectives functional, which return the truth value of a proposition based on the truth value of connected propositions (Wikipedia)

questions, that is, “do the paths differ between SMEs and large companies to obtain a high intensity of new external relationships?”.

The answer to this question seems to be affirmative. The dimension of the firm had an impact on all the identified paths defining different conditions involved.

From the results, direct relation with the end-user firm must be present for both paths in which SMEs are involved. On the other hand, large companies with a high level of participation in the project of available internal skills can have the absence of this condition. The high importance of service in the strategy is a relevant condition only for non-large companies. In addition, high digital readiness is present only in the path for large companies suggesting that digital readiness may require some capabilities that are only present in large companies.

To conclude, a further analysis about typologies and characteristics of the identified new external relationships may be seen as a possible topic of discussion and analysis to extend this model. To do so, a deeper understand of which is the correlation between the characteristics of the involved firms and the ecosystem of manufacturing companies in Italy is needed. Only in this way the model might be extended to lay the foundations of new managerial guidelines in product-service system shifts.

Bibliography

Adrodegari, F., Pashou, T., & Saccani, N. (2017). Business Model Innovation: Process and Tools for Service Transformation of Industrial Firms. *Procedia CIRP*, *64*, 103–108. https://doi.org/10.1016/j.procir.2017.03.056

Ayala, N. F., Paslauski, C. A., Ghezzi, A., & Frank, A. G. (2017). Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *International Journal of Production Economics*, *193*, 538–553. https://doi.org/10.1016/j.ijpe.2017.08.019

Baines, T., Ziaee Bigdeli, A., Bustinza, O. F., Shi, V. G., Baldwin, J., & Ridgway, K. (2017). Servitization: revisiting the state-of-the-art and research priorities. *International Journal of Operations and Production Management*, *37*(2), 256–278. https://doi.org/10.1108/IJOPM-06-2015-0312

Bottani, E., & Vignali, G. (2019). Augmented reality technology in the manufacturing industry: A review of the last decade. *IISE Transactions*, *51*(3), 284–310. https://doi.org/10.1080/24725854.2018.1493244

Canhoto, A. I., & Clear, F. (2020). Artificial intelligence and machine learning as business tools: A framework for diagnosing value destruction potential. *Business Horizons*, *63*(2), 183–193. https://doi.org/10.1016/j.bushor.2019.11.003

Chesbrough, H. (2007). Business model innovation: It's not just about technology anymore. *Strategy and Leadership*, *35*(6), 12–17. https://doi.org/10.1108/10878570710833714

Clarke, K. A. (2020). Logical constraints: The limitations of QCA in social science research. *Political Analysis*, *28*(4), 552–568. https://doi.org/10.1017/pan.2020.7

Clauss Thomas. (2016). Measuring business model innovation: conceptualization, scale development, and proof of performance. *R&D Management*, *47*(3), 385–403. https://doi.org/10.1111/radm.12186

Cusumano, M. A., Kahl, S. J., & Suarez, F. F. (2015). Services, industry evolution, and the competitive strategies of product firms. *Strategic Management Journal*, *36*(4), 559–575. https://doi.org/10.1002/smj.2235

Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy*, *39*(6), 699–709. https://doi.org/10.1016/j.respol.2010.01.013

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

de Carolis, A., Macchi, M., Negri, E., & Terzi, S. (2017). A maturity model for assessing the digital readiness of manufacturing companies. *IFIP Advances in Information and Communication Technology*, *513*, 13–20. https://doi.org/10.1007/978-3-319-66923-6_2

Dmitrijeva, J., Schroeder, A., Ziaee Bigdeli, A., & Baines, T. (2020). Context matters: how internal and external factors impact servitization. *Production Planning and Control*, *31*(13), 1077–1097. https://doi.org/10.1080/09537287.2019.1699195

Fiss, P. C. (2007). A set-theoretic approach to organizational configurations. *Academy of Management Review*, *32*, 1180–1198.

França, C. L., Broman, G., Robèrt, K. H., Basile, G., & Trygg, L. (2017). An approach to business model innovation and design for strategic sustainable development. *Journal of Cleaner Production*, *140*, 155–166. https://doi.org/10.1016/j.jclepro.2016.06.124

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019a). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*, 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019b). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*, 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Gebauer H., Paiola M., Saccani N. and Rapaccini M. (2021), "Digital servitization: Crossing the perspectives of digitization and servitization", *Industrial Marketing Management*, 93, 382-388, https://doi.org/10.1016/j.indmarman.2020.05.011

Haller, S. (n.d.). *The Things in the Internet of Things*. http://www.iot2010.org/

Kastalli, I. V., van Looy, B., & Neely, A. (2013). Steering manufacturing firms towards service business model innovation. *California Management Review*, *56*(1), 100–123. https://doi.org/10.1525/cmr.2013.56.1.100

Kohtamäki, M., Parida, V., Patel, P. C., & Gebauer, H. (2020). The relationship between digitalization and servitization: The role of servitization in capturing the financial potential of digitalization. *Technological Forecasting and Social Change*, *151*. https://doi.org/10.1016/j.techfore.2019.119804

Kohtamäki, M., Rabetino, R., Einola, S., Parida, V., & Patel, P. (2021). Unfolding the digital servitization path from products to product-service-software systems: Practicing change through intentional narratives. *Journal of Business Research*, *137*, 379–392. https://doi.org/10.1016/j.jbusres.2021.08.027

Lasagni, A. (2012). How Can External Relationships Enhance Innovation in SMEs? New Evidence for Europe*j sbm_355 310..339. *Journal of Small Business Management 5*, *50*(2), 310–339.

Llopis-Albert, C., Rubio, F., & Valero, F. (2021). Impact of digital transformation on the automotive industry. *Technological Forecasting and Social Change*, *162*. https://doi.org/10.1016/j.techfore.2020.120343

Marx, A., Rihoux, B., & Ragin, C. (2014a). The origins, development, and application of Qualitative Comparative Analysis: The first 25 years. In *European Political Science Review* (Vol. 6, Issue 1, pp. 115–142). https://doi.org/10.1017/S1755773912000318

Marx, A., Rihoux, B., & Ragin, C. (2014b). The origins, development, and application of Qualitative Comparative Analysis: The first 25 years. In *European Political Science Review* (Vol. 6, Issue 1, pp. 115–142). https://doi.org/10.1017/S1755773912000318

Mikalef, P., Krogstie, J., & Pavlou, P. (2019). *Big data and business analytics: A research agenda for realizing business value*. https://www.researchgate.net/publication/337543997

Mont, O. (2014a). *Introducing and Developing a Product-Service System (PSS) Concept in Sweden*. https://www.researchgate.net/publication/228863029

Mont, O. (2014b). *Introducing and Developing a Product-Service System (PSS) Concept in Sweden*. https://www.researchgate.net/publication/228863029

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132*, 2–17. https://doi.org/10.1016/j.techfore.2017.12.019

Niaki, M. K., & Nonino, F. (2017). Impact of additive manufacturing on business competitiveness: A multiple case study. *Journal of Manufacturing Technology Management*, *28*(1), 56–74. https://doi.org/10.1108/JMTM-01-2016-0001

Pagani, M., & Pardo, C. (2017). The impact of digital technology on relationships in a business network. *Industrial Marketing Management*, *67*, 185–192. https://doi.org/10.1016/j.indmarman.2017.08.009

Paiola, M., Schiavone, F., Grandinetti, R., & Chen, J. (2021). Digital servitization and sustainability through networking: Some evidences from IoT-based business models. *Journal of Business Research*, *132*, 507–516. https://doi.org/10.1016/j.jbusres.2021.04.047

Raddats, C., & Easingwood, C. (2010). Services growth options for B2B product-centric businesses. *Industrial Marketing Management*, *39*(8), 1334–1345. https://doi.org/10.1016/j.indmarman.2010.03.002

Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics*, *192*, 92–105. https://doi.org/10.1016/j.ijpe.2017.02.016

Schneider, C. Q., & Wagemann, C. (2010). Standards of good practice in qualitative comparative analysis (QCA) and fuzzy-sets. *Comparative Sociology*, *9*(3), 397–418. https://doi.org/10.1163/156913210X12493538729793

Seny Kan, A. K., Adegbite, E., el Omari, S., & Abdellatif, M. (2016). On the use of qualitative comparative analysis in management. *Journal of Business Research*, *69*(4), 1458–1463. https://doi.org/10.1016/j.jbusres.2015.10.125

Sjödin, D., Parida, V., & Kohtamäki, M. (2019). Relational governance strategies for advanced service provision: Multiple paths to superior financial performance in servitization. *Journal of Business Research*, *101*, 906–915. https://doi.org/10.1016/j.jbusres.2019.02.042

Smari, W. W., Fox, G. C., Nygård, M., & Institute of Electrical and Electronics Engineers. (2014). *Defining Architecture Components of the Big Data EcosystemMinnesota*.

Stachová, K., Papula, J., Stacho, Z., & Kohnová, L. (2019). External partnerships in employee education and development as the key to facing industry 4.0 challenges. *Sustainability (Switzerland)*, *11*(2). https://doi.org/10.3390/su11020345

Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection*, *118*, 254–267. https://doi.org/10.1016/j.psep.2018.06.026

Thomas, J., & Brunton, G. (2014). *Using qualitative comparative analysis (QCA) in systematic reviews of complex interventions: a worked example*. http://www.systematicreviewsjournal.com/content/3/1/67

Ulaga, W., Reinartz, W. J., Gartmeier, V., Lévèque, L., Orbach, D., van Putten, V., & Lobschat, L. (2011). Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully From a scholarly perspective, we know a great deal about the processes, antecedents, and consequences of designing and. *Journal of Marketing*, *75*, 5–23.

Vasantha, G. V. A., Roy, R., Lelah, A., & Brissaud, D. (2012). A review of product-service systems design methodologies. In *Journal of Engineering Design* (Vol. 23, Issue 9, pp. 635–659). https://doi.org/10.1080/09544828.2011.639712

Visnjic, I., Wiengarten, F., & Neely, A. (2016). Only the Brave: Product Innovation, Service Business Model Innovation, and Their Impact on Performance. *Journal of Product Innovation Management*, *33*(1), 36–52. https://doi.org/10.1111/jpim.12254

Visnjic Kastalli, I., & van Looy, B. (2013). Servitization: Disentangling the impact of service business model innovation on manufacturing firm performance. *Journal of Operations Management*, *31*(4), 169–180. https://doi.org/10.1016/j.jom.2013.02.001

Wagemann, C., Buche, J., & Siewert, M. B. (2016). QCA and business research: Work in progress or a consolidated agenda? *Journal of Business Research*, *69*(7), 2531–2540. https://doi.org/10.1016/j.jbusres.2015.10.010

Wallin, J., Parida, V., & Isaksson, O. (2015). Understanding product-service system innovation capabilities development for manufacturing companies. *Journal of Manufacturing Technology Management*, *26*(5), 763–787. https://doi.org/10.1108/JMTM-05-2013-0055

Wamba-Taguimdje, S. L., Fosso Wamba, S., Kala Kamdjoug, J. R., & Tchatchouang Wanko, C. E. (2020). Influence of artificial intelligence (AI) on firm performance: the business value of AI-based transformation projects. *Business Process Management Journal*, *26*(7), 1893–1924. https://doi.org/10.1108/BPMJ-10-2019-0411

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks*, *2016*. https://doi.org/10.1155/2016/3159805

Xue, C. T. S., & Xin, F. T. W. (2016). Benefits and Challenges of the Adoption of Cloud Computing in Business. *International Journal on Cloud Computing: Services and Architecture*, *6*(6), 01–15. https://doi.org/10.5121/ijccsa.2016.6601

Annex

Survey questions: Italian

1. Qual è il prodotto/business principale della sua azienda?

2. Di quale classe dimensionale è la sua impresa?

   a. Micro-impresa (<10 dipendenti)
   b. Piccola impresa (<50 dipendenti)
   c. Media impresa (<250 dipendenti)
   d. Grande impresa (<1000 dipendenti)
   e. Grandissima impresa (>1000 dipendenti)

3. Quanto reputa sia importante attualmente il ruolo dei servizi al cliente nella strategia competitiva della sua impresa? (1-per nulla importante – 7 – estremamente importante)

4. Fornisca un'autovalutazione sulla *readiness* digitale della sua azienda (livello di uso strumenti quali ERP, MES, CRM, workflow management, meeting platforms, etc.) (1-per nulla pronti – 7-estremamente pronti)

5. Valuti le seguenti tecnologie per intensità di utilizzo all'interno dell'azienda (1-non utilizzato – 7-molto utilizzato)

- Data analysis e Big Data
- Industria 4.0 (machine di produzione connesse)
- Intelligenza artificiale e Machine Learning
- Integrazione dei sistemi informativi con fornitori (produzione collaborativa)
- Internet of Things e Industrial IoT
- Cybersecurity
- Cloud/Edge computing
- Additive Manufacturing (3D printing)
- Realtà aumentata/virtuale

6. Su cosa si baserà in futuro il valore nel suo business? (1-Per nulla – 7-Moltissimo)

- Prodotto
- Software

- Servizio
- Comunicazione

7. La sua azienda ha una relazione diretta con l'azienda-cliente utilizzatrice del prodotto (final user firm)?

a) Si (con tutte o in prevalenza)
b) No (con nessune o in prevalenza)

8. In quale anno ha avuto inizio il progetto di utilizzo delle tecnologie digitali (IoT, Cloud, data analysis) per i servizi al prodotto nella sua azienda?

9. In quale fase di sviluppo del progetto ritiene siate attualmente?

a) Early stage, POC o MVP
b) Introduction, abbiamo un prototipo non ancora distribuito o in uso a pochi clienti
c) Development, abbiamo affinato le soluzioni e cominciato la distribuzione e vendita
d) Maturity, i servizi digitali hanno pricing, fatturato e mercato da almeno un anno

10. Chi è stato il promotore dei servizi digitali nella sua azienda?

a) Il servizio post-vendita
b) R&D, sviluppo prodotti
c) Marketing e vendite
d) La direzione
e) Altro

11. C'è stato un (o più) clienti key o cliente pilota che vi ha aiutato nel progetto?

a) Si
b) No

12. Ritiene che la relazione con tale/i cliente/i sia tuttora rilevante per il vostro progetto di servizi digitali? (1-per nulla importante – 7-estremamente importante)

13. Quanti sono attualmente i prodotti (base installata) connessi?

14. Quali dei seguenti servizi digitali vengono offerti alla vostra clientela? (sceglierne una o più)

- Documentazione online sul prodotto
- Portale e-commerce dedicato a ricambi e materiali (per preventivazione e/o vendita diretta)
- Monitoraggio remoto e web/digital application per il cliente
- Monitoraggio remoto con control room
- Help-desk tecnico per il cliente integrato con il monitoraggio remoto
- Interventi di service con realtà aumentata
- Contratti di manutenzione predittiva
- Contratti di pay per use
- Contratti di servizio parametrati ai risultati
- Altro

15. I servizi digitali che proponete alla clientela sono: (1-fortemente in disaccordo – 7-totalmente d'accordo)

- Fortemente personalizzati
- Personalizzabili a richiesta
- Il più possibile standard

16. I vostri servizi/soluzioni sono:

a) Industry-specific: adatti esclusivamente al proprio settore industriale (non utilizzabile altrove)
b) Cross-industry: adatti ad essere utilizzati in altri settori (anche potenzialmente)
c) Non-specific: utilizzabili in tutti i settori (il focus è sulla soluzione)

17. Qual è stato, ad oggi, l'impatto dei servizi digitali sulle diverse aree del business model? (1-molto limitato – 7-molto rilevante)

- Impatto sull'area di value creation (attività ed operation, risorse e competenze, partnership e fornitori)
- Impatto sulla value proposition (tipo di promessa e comunicazione fatta al cliente)

- Impatto sull'area di value distribution (relazioni con i clienti, canali di distribuzione, segmenti di mercato)
- Impatto sui costi
- Impatto sui ricavi

18. Per quanto riguarda le competenze nel progetto:

- N. totale di persone impegnate in via esclusiva nel progetto: _____
- (di cui) N. di persone assunte ad-hoc per il progetto: _____
- (di cui) N. di persone che si occupano specificatamente di analisi dei dati: _____

19. Quanto è rilevante il contributo delle competenze interne all'azienda al progetto servizi digitali nelle seguenti aree? (1-limitato – 7-totale o N/D)

- Automazione
- Device IoT e connettività
- Scrittura software
- Data Analysis
- Data visualization
- UX/Interaction
- Sviluppo offerta e applicazioni
- Vendita e comunicazione
- Altro

20. Come valuta il livello di partecipazione delle competenze interne al progetto? (1-estremamente inferiore alle potenzialità interne – 7-Massima possibile)

21. Come valuta la risposta dell'azienda (nel suo complesso) al progetto di digitalizzazione? (1-Risposta negativa e basso adattamento – 7-Risposta positiva e massimo appoggio)

22. In quale area reputa vi sia stata la maggiore resistenza?

a) R&D e sviluppo prodotti
b) Commerciale e marketing
c) Servizio post-vendita
d) Direzione centrale

e) Altro

23. Indichi il numero di relazioni esterne attivate ex-novo specificatamente per il progetto: _____

24. Circa il numero di relazioni esterne indicate nella domanda precedente, quante di esse:

- Hanno sostituito relazioni esistenti _____
- Si sono affiancate a relazioni esistenti _____
- Sono relative a tecnologia (software, cloud, AR/AI, piattaforme) _____
- Sono relative a servizi di tipo gestionale e organizzativo _____

25. Quale importanza hanno i seguenti fattori nella gestione delle relazioni esterne collegate ai servizi digitali? (1-per nulla importante – 7-estremamente importante)

- Regolazione contrattuale
- Ruolo di fiducia (trust)
- Frequenza rapporti (closeness)
- Livello di condivisione attività e decisioni (adaptation)
- Frequenza riunioni di coordinamento con partner esterni

26. Che ruolo ha l'impresa nelle relazioni con l'esterno attivate per i servizi digitali?

a) Orchestra i contributi esterni, i fornitori interagiscono tra loro
b) Orchestra i contributi esterni, i fornitori non interagiscono tra loro
c) Progetta internamente e affida il lavoro all'esterno
d) Affida progettazione ed esecuzione soluzioni all'esterno

27. Quali cambiamenti ritiene auspicabili per il futuro?

- Internalizzazione di alcune risorse e attività
- Esternalizzazione di attività specialistiche
- Partnership con aziende specialistiche
- Acquisizioni specifiche di aziende esterne
- Creazione di una BU specifica
- Prevedibilità dei cambiamenti AB
- Altro

28. Ci lasci un suo recapito email per ricevere il report della ricerca (trattamento riservato ex art. 13 D. Lgs. 196/2003): _____

29. Se ha qualche ulteriore commento può lasciarlo nello spazio seguente, grazie _____

Survey questions: translated in English

1. What is the main product/business of your company?

2. What size class is your company in?

a. Micro-enterprise (<10 employees)
b. Small enterprise (<50 employees)
c. Medium enterprise (<250 employees)
d. Large enterprise (<1000 employees)
e. Very large enterprise (>1000 employees)

3. How important do you think the role of customer services currently is in your firm's competitive strategy? (1-not at all important - 7 - extremely important)

4. Please provide a self-assessment of your company's digital readiness (level of use of tools such as ERP, MES, CRM, workflow management, meeting platforms, etc.) (1-not at all ready - 7-extremely ready)

5. Rate the following technologies by intensity of use within your company (1-not at all used - 7-very used)

- Data analysis and Big Data
- Industry 4.0 (connected production machines)
- Artificial Intelligence and Machine Learning
- Integration of information systems with suppliers (collaborative production)
- Internet of Things and Industrial IoT
- Cybersecurity
- Cloud/Edge computing
- Additive Manufacturing (3D printing)
- Augmented/Virtual Reality

6. What will value in your business be based on in the future? (1-For nothing - 7-Much)

- Products
- software
- Service
- Communication

7. Does your company have a direct relationship with the company-customer who uses the product (final user firm)?

a) Yes (with all or prevalently)
b) No (with none or mostly)

8. In what year did the project to use digital technologies (IoT, Cloud, data analysis) for product services begin in your company? _____

9. What stage of project development do you believe you are currently in?

a) Early stage, POC or MVP
b) Introduction, we have a prototype not yet deployed or in use by a few customers
c) Development, we have refined the solutions and begun distribution and sales
d) Maturity, digital services have had pricing, revenue and market for at least one year

10. Who has been the driving force behind digital services in your company?

a) After-sales service
b) R&D, product development
c) Marketing and sales
d) Management
e) Other

11. Was there a key customer(s) or pilot customer(s) that helped you with the project?

a) Yes
b) No

12. Do you feel that the relationship with that customer(s) is still relevant to your digital services project? (1-not at all important - 7-extremely important)

13. How many products (installed base) are currently connected?

14. Which of the following digital services are offered to your customer base? (choose one or more)

- Online product documentation
- Dedicated e-commerce portal for parts and materials (for quotation and/or direct sales)
- Remote monitoring and web/digital application for the customer
- Remote monitoring with control room
- Technical help-desk for the customer integrated with remote monitoring
- Service interventions with augmented reality
- Predictive maintenance contracts
- Pay per use contracts
- Service contracts based on results
- Other

15. The digital services you offer to customers are: (1-strongly disagree - 7-totally agree)

- Strongly personalized
- Customizable on demand
- As standard as possible

16. Your services/solutions are:

a) Industry-specific: suitable exclusively for your industry (not usable elsewhere)
b) Cross-industry: suitable for use in other sectors (even potentially)
c) Non-specific: usable in all sectors (the focus is on the solution)

17. What has been, to date, the impact of digital services on different areas of the business model? (1-very limited - 7-very relevant)

- Impact on the area of value creation (activities and operations, resources and skills, partnerships and suppliers)
- Impact on value proposition (type of promise and communication made to the customer)
- Impact on the area of value distribution (customer relationships, distribution channels, market segments)

- Impact on costs
- Impact on revenues

18. Regarding skills in the project:

- Total no. of people exclusively engaged in the project: _____
- (of which) No. of people hired ad-hoc for the project: _____
- (of which) No. of people specifically involved in data analysis: _____

19. How relevant is the contribution of in-house expertise to the digital services project in the following areas? (1-limited - 7-total or N/A)

- Automation
- IoT devices and connectivity
- Software writing
- Data Analysis
- Data visualization
- UX/Interaction
- Offer and application development
- Sales and communication
- Other

20. How do you rate the level of participation of internal expertise in the project? (1-Extremely below internal potential - 7-Maximum possible)

21. How do you rate the company's response (as a whole) to the digitization project? (1-Negative response and low adaptation - 7-Positive response and maximum support)

22. In which area do you feel there has been the most resistance?

a) R&D and product development
b) Sales and marketing
c) After-Sales Service
d) Central management
e) Other

23. Indicate the number of external relations activated ex-novo specifically for the project: _____

24. About the number of external relationships indicated in the previous question, how many of them:

- Have replaced existing relationships _____
- They complemented existing relationships _____
- Related to technology (software, cloud, AR/AI, platforms) _____
- Are related to management and organizational services _____

25. How important are the following factors in managing external relationships related to digital services? (1-not at all important - 7-extremely important)

- Contractual regulation
- Role of trust
- Frequency of relationships (closeness)
- Level of sharing of activities and decisions (adaptation)
- Frequency of coordination meetings with external partners

26. What role does the firm play in the external relationships established for digital services?

a) Orchestrate external contributions, suppliers interact with each other.
b) Orchestrates external contributions, suppliers do not interact with each other
c) Design internally and outsource work.
d) Outsource design and execution of solutions

27. What changes do you consider desirable for the future?

- Internalization of some resources and activities
- Outsourcing of specialist activities
- Partnerships with specialist companies
- Specific acquisitions of external companies
- Creation of a specific BU
- Predictability of AB changes
- Other

28. Leave us your email address to receive the report of the research (confidential treatment ex art. 13 D. Lgs. 196/2003): _____

29. If you have any further comments please leave them in the following space, thanks

_____