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Barriers to Digital Servitization Adoption: Case Studies looking at key Challenges and Stakeholders

Graduation paper presented to Escola Politécnica da Universidade de São Paulo to obtain the degree of Production Engineer.

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To my family for always supporting my dreams

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RESUMO

Esta pesquisa teve como objetivo a identificação, a categorização e a priorização dos principais desafios enfrentados pelas organizações na implementação da servitização digital, por meio de revisão da literatura, pesquisa de campo e análise qualitativa. A categorização proposta nesta tese inclui: barreiras de estratégia, organizacionais, operacionais, financeiras, tecnológicas, ambientais, de contexto de negócios e de cadeia de suprimentos. O método de priorização considerou os benefícios financeiros e não financeiros esperados e o tempo e os recursos financeiros necessários para superar as barreiras, usando evidências empíricas. A partir da análise qualitativa, foi possível perceber que as barreiras específicas de país (relativas a desafios culturais e de infraestrutura, por exemplo) são muito desafiadoras para as empresas que implementam a servitização digital e que enfrentar o desafio relacionado à capacidade de comunicar e vender a oferta está entre as prioridades dos profissionais. Além da investigação dos desafios, foram identificados os atores da cadeia de suprimentos e foram feitas considerações sobre o cenário brasileiro, com base nos estudos de caso. As limitações deste trabalho incluem o restrito número de empresas entrevistadas e a falta de avaliação das relações causais entre as barreiras.

Palavras-chave: Servitização digital. Barreiras. Priorização.

ABSTRACT

This research aimed the identification, categorization, and prioritization of the main challenges faced by organizations in implementing digital servitization, through literature review, field research, and qualitative analysis. The categorization proposed in this thesis includes Strategy, Organization, Operational, Financial, Technological, Environmental, Business Context and Supply Chain barriers. The prioritization method considered the expected financial and non-financial benefits and the time and financial resources needed to overcome the barriers, using empirical evidence. From the qualitative analysis, it was possible to notice that country specific barriers (relating to cultural and infrastructure challenges, for example) are very challenging for firms implementing digital servitization, and that tackling the challenge related to the capability to communicate and sell the offer is among the priorities for practitioners. Besides the challenges' investigation, supply chain actors were identified and considerations on the Brazilian scenario were made, based on the case studies. The limitations of this work include the restrict number of firms interviewed, and lack of evaluation on causal relationships among barriers.

Keywords: Digital Servitization. Barriers. Prioritization.

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LIST OF ABBREVIATIONS AND ACRONYMS

DPSS – Digitalized Product-Service Systems

GDPR – General Data Protection Regulation

IoT – Internet of Things

LGPD – Lei Geral de Proteção de Dados

PSS – Product-Service Systems

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1 INTRODUCTION

In this section, the drive and purpose behind the thesis are introduced. Subsequently, there is a brief overview of how the project is organized.

1.1 Motivation

By combining products, services, software, and analytics with the support of technology (PASCHOU et al., 2020), companies are aiming to gain a competitive advantage through the adoption of digitalized product-service systems (DPSS). Indeed, through the use of digital technologies, such as Internet of Things (IoT), big data, analytics, and cloud computing, several companies are currently generating useful knowledge from data collection and analysis and creating value through co-creation with customers. In this way, given the growing adoption of this business model, the study of digital servitization implementation is timely and pertinent.

There are many benefits in adopting digital servitization: more customizable, flexible, and time-efficient services to customers, and better image, customer lifetime value and profitability to companies (VENDRELL-HERRERO et al., 2017). Moreover, these bundles of goods and services are differentiating, lasting, and easier to secure from competitors (BAINES, 2009).

However, despite the benefits, it may not be easy for firms to transform their processes when moving towards digital servitization. It may require organizational change, and a reconfiguration of business models (PASCHOU et al., 2020), generating several challenges. For instance, digital servitization may impact firms' facilities, technologies, organizational processes, (BAINES; LIGHTFOOT; SMART, 2011), cost structure (PURVIS et al., 2021), and power relations among the supply chain (VENDRELL-HERRERO et al., 2017; MOSCH; SCHWEIKL; OBERMAIER, 2021).

Therefore, the identification, segmentation, and prioritization of the several challenges and barriers associated with digital servitization, investigated in this thesis, are essential for companies willing to pursue such a complex strategy. In the present thesis, the challenges found in the literature are consolidated and divided into categories, facilitating their identification and understanding by practitioners.

Moreover, despite the work of many authors in identifying barriers for digital servitization and possible actions to tackle such problems, the literature is still emergent in their prioritization, which is of crucial relevance, given the limited managerial and financial

resources of firms (SPINLER; WERNING, 2020). Indeed, WEERABAHU et al., 2022 states that their work is the first one to attempt to prioritize the barriers to digital servitization in the manufacturing sector with empirical evidence. Nevertheless, in their work, the expected benefits and the time and financial resources needed to overcome the barriers are not mentioned. In fact, their study focuses on the prioritization of the barriers considering their overall influence in terms of their relationship with other factors and/or barriers, and causal relationships.

Therefore, this thesis will generate additional value to the literature by prioritizing barriers through measuring the effort needed to overcome each barrier and their corresponding contribution to the creation of value for companies, in an empirical way. Moreover, by interviewing companies with presence in Brazil, this thesis answers to KAMAL et al., 2020 proposition to investigate digital servitization practices in emerging economies, giving their increasing significance and low attention in the literature.

1.2 Objectives

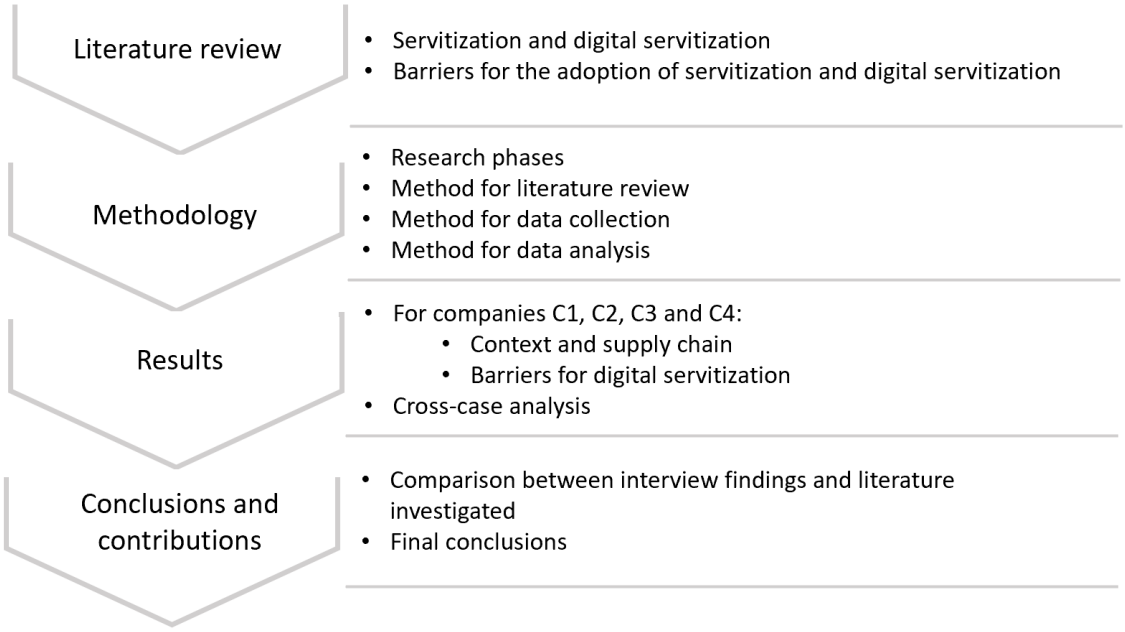
The aim of this work is to identify, categorize, and prioritize the primary challenges encountered by firms adopting digital servitization as their business model. Additionally, it seeks to recognize the involvement of various actors in delivering digital-servitized offerings. In this way, the thesis objectives are to:

- 1: Identify, summarize and categorize the key obstacles faced by organizations in implementing digital servitization, drawing from existing literature.
- 2: Identify and categorize barriers to digital servitization adoption within organizations, as well as pinpoint the stakeholders involved in Digitalized Product-Service Systems (DPSS) offerings, through semi-structured interviews.
- 3: Evaluate barriers encountered by each interviewed company in terms of difficulty to surmount (financial and temporal constraints) and associated benefits (both economic and non-economic), utilizing a prioritization graph with two axes.
- 4: Conduct a comparative analysis of interview results across cases and against existing literature to authenticate and extend the research's conclusions.

1.3 Structure

This paper is structured in four chapters: Literature Review, Methodology, Results, and Conclusions and contributions, as shown in Figure 1.

Figure 1 – Thesis structure



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- Literature review: this chapter presents the description of topics of interest, including servitization, digital servitization, and challenges faced by companies implementing these business models. The challenges are divided into eight main categories: strategic, operational, organizational, financial, technological, supply chain, business context and environmental
- Methodology: this chapter describes each phase of the study and the methods adopted for literature review, data collection and analysis.
- Results: this chapter shows the qualitative analysis results, from each interview analyzed separately, and a cross-case analysis.
- Conclusion and contributions: this chapter conveys the objectives, highlights the main field evidence and compare it with the literature review.

2 LITERATURE REVIEW

In this chapter the description of topics of interest are presented. The topics are servitization, digital servitization, and challenges faced by companies implementing these business models. The challenges are divided into eight main categories: strategic, operational, organizational, financial, technological, supply chain, business context and environmental.

2.1 Servitization

According to BAINES et al., 2009, servitization is the shift from selling products to selling integrated products and services, PSS (Product-Service System), that deliver value in use. These integrated offerings can occur through different forms on a continuum ranging from products with "add-on" services, where the main value offered to the customer derives from the physical goods, to services with "add-on" products, where the provision of services are fundamental value-added activities.

TUKKER, 2004 suggested a categorization of PSS into product-oriented, use-oriented, and result-oriented types. In product-oriented PSS, the business model is mainly geared towards sales of products, with the addition of extra services. In this main category are included: 1) Product-related services, which are needed during the use phase of the product, such as maintenance contracts, financing schemes, supply of consumables, and take-back agreements (when the product reaches its end of life); 2) Advice and consultancy services, in which the provider gives advice on the products' most efficiency use.

The second main category is use-oriented PSS, in which the traditional product still plays a central role, but, instead of focusing on selling products, the products' ownership remains with the provider. In this main category are included: 1) Product lease, in which the provider maintains the product ownership and the user pays a regular fee for the unlimited and individual use of the product; 2) Product renting or sharing, in which the product is owned by the provider, and the user pays a fee for its use. However, differently from product lease, the same product is sequentially used by different users; 3) Product pooling, which resembles product renting or sharing. However, in this case, there is a simultaneous use of the product by different users (TUKKER, 2004).

The last main category is result-oriented PSS, in which the client and provider agree on a result, and there is no pre-determined product involved. In this main category are included: 1) Activity management/outsourcing, where an activity is outsourced to a third party, via an

outsourcing contract with performance indicators; 2) Pay per service unit, where the user buys the output of the product, such as pay-per-print formulas adopted by some copier producers; 3) Functional result, in which the provider delivers a functional result in rather abstract terms, not directly related to a specific system (TUKKER, 2004).

These bundles of goods and services are differentiating, lasting, and easier to secure from competitors. Moreover, through the service orientation, manufacturing firms aim to have higher profit margins, stability of income, and marketing opportunities, as the addition of services may positively influence the customers' purchasing decision, especially in B2B markets (BAINES et al., 2009).

Services are also relevant for the creation of customer loyalty and for gaining insights into the customers' needs. Indeed, an important aspect of servitization strategies is a strong customer centricity, in which customers are provided with more tailored solutions. As stated in FINNE; HOLMSTROM, 2013, the establishment of relationships with the end user of the product is fundamental, as final consumers supply installed base information and field service premises, that are necessary for providing industrial services.

2.2 Digital servitization

With the emergence of Industry 4.0, manufacturers are increasingly combining sensor-equipped components of their traditional products with digital technologies to offer services, aiming to gain a competitive advantage through digitalized product-service systems (DPSS). This shift from providing physical products to offering DPSS is commonly known as digital servitization (MOSCH; SCHWEIKL; OBERMAIER, 2021). In other words, digital servitization is the creation and delivery of integrated solutions composed by the combination of products, services, software, and analytics with the support of technology, such as Information and Communication Technologies (ICT) or other digital technologies (PASCHOU et al., 2020).

Through the adoption of digital technologies, such as Internet of Things (IoT), big data, analytics, and cloud computing, companies can generate useful knowledge from data collection and analysis and create value through co-creation with customers. For instance, IoT technology can be used for real-time monitoring of engine data, allowing aviation firms to provide better maintenance services for their customers.

Moreover, the provision of digital services embedded in physical goods (VENDRELL-HERRERO et al., 2017), allows customers to receive more customizable, flexible, and time-

efficient services, while providers, given the improvement of the customers' experience, enhance their image, increase customer lifetime value and profitability. Thus, digital servitization enables companies to improve their product-service bundles, increase their competitive advantage and strengthen their operational and environmental performance.

Besides the benefits described, it is important to mention that firms transform their processes when moving towards digital servitization. This occurs as they shift from a product-centric to a service-centric logic, while leveraging on digital technologies, requiring organizational change, and a reconfiguration of business models (PASCHOU et al., 2020).

2.2.1 Differences between services and digital services

MOSCH; SCHWEIKL; OBERMAIER, 2021 highlights four main differences between services and digital services. First, digital services exhibit higher scalability, as they can be replicated with exceptionally low marginal costs. Second, digital services diminish the significance of physical materiality in value creation, while traditional services tend to complement physical products. Third, regarding companies' infrastructure, the provision of digitalized product-service systems necessitates a more centralized organizational structure and data-driven platforms. Fourth, considering the competencies required to provide DPSS, it is argued that companies often lack some of the required abilities, such as knowledge over end users and the installed base and/or expertise on the product's technology. In that way, the importance of cooperations between different actors in the network of the DPSS is significantly higher. Finally, MOSCH; SCHWEIKL; OBERMAIER, 2021 mention new market entry opportunities, and changing power structures in supply chains and entire industry segments, due to the digital servitization.

2.3 Challenges to servitization and digital servitization

To adopt servitization and digital servitization as competitive manufacturing strategies and exploit higher value business activities, companies face several challenges. Digital servitization may impact firms' facilities, technologies, organizational processes, (BAINES; LIGHTFOOT; SMART, 2011), cost structure (PURVIS et al., 2021), and power relations among the supply chain (VENDRELL-HERRERO et al., 2017; MOSCH; SCHWEIKL; OBERMAIER, 2021). Firms may also have to face competition outside their usual domain,

manage to describe the new value proposition to the customer (BAINES, 2009), among other obstacles.

Indeed, by increasing services' provision and the utilization of modern technologies, companies may face radical changes in their current processes, which calls for a complex re-design (PURVIS et al., 2021). Therefore, the identification, segmentation, and prioritization of the several challenges and barriers associated with digital servitization is essential for companies willing to pursue such a complex strategy.

To identify and summarize the main challenges companies may encounter, a systematic literature review was conducted. Such challenges are here divided into eight categories: strategic (STR), operational (OPE), organizational (ORG), financial (FIN), technological (TEC), supply chain (SC), business context (BUS) and environmental (ENV).

Table 1 summarizes the eight main categories, its subcategories, and the articles that mention each barrier. The references for the articles are displayed in Appendix B. The articles used for the barriers' collection were selected following the methodology explained in the literature methodology session. Additional articles were included by recommendation of the thesis' advisors.

Table 1 – Main barriers categorization

Level 1	Level 2	Code	Reference	#
Strategic (STR)	Design of offer and portfolio	STR01	[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], and [19]	19
	Development and/or buy new competencies	STR02	[1], [4], [7], [9], [10], [11], [12], [13], [15], [18], [19], [20], [21], [22], [23], [24], [25], and [26]	18
	Access to strategic relationships and/or information	STR03	[7], [9], [14], [18], [19], [22], [24], [26], and [27]	9
	Focus and image	STR04	[1], [2], [4], [7], [9], [10], [18], [19], and [21]	9

	Management commitment, competencies, and resources	STR05	[1], [4], [7], [9], [11], [15], [17], and [18]	8
	Changing/complex business models and methods	STR06	[4], [7], [15], [17], and [18]	5
	Lack of vision and understanding	STR07	[5], [9], [17], and [18]	4
	Strategic risks and risk management	STR08	[13] and [18]	2
	Servitized offer cannibalizing physical products	STR09	[24]	1
Operational (OPE)	Support and service delivery	OPE01	[3], [5], [6], [7], [8], [9], [10], [11], [13], [17], [19], [23], [24], and [27]	14
	Customer collaboration and behavior	OPE02	[1], [4], [5], [11], [13], [17], [21], [22], and [27]	9
	Capability to communicate and sell the offer	OPE03	[1], [2], [4], [8], [9], [14], [17], and [19]	8
	Measurement of performance and savings	OPE04	[5], [11], [15], and [17]	4
	Internal communication and information flows	OPE05	[5], [8], [13], and [23]	4
	Adoption of defined processes	OPE06	[7], [9], [14], and [19]	4
	Operational risks	OPE07	[13], [17], and [18]	3
	Complexity from digitalized products and/or processes	OPE08	[9] and [27]	2
Organizational (ORG)	Culture shift, resistance/fear, and awareness	ORG01	[1], [2], [4], [5], [7], [8], [9], [10], [11], [15],	15

			[17], [18], [19], [21], and [26]	
	Organizational design and knowledge management	ORG02	[1], [5], [7], [8], [9], [11], [12], [13], [18], and [19]	10
	Internal conflicts and silos	ORG03	[4], [5], [9], [14], [15], [17], [18], [19], and [26]	9
	Training and hiring	ORG04	[15], [17], and [27]	3
Financial (FIN)	Profitability and pricing	FIN01	[1], [4], [5], [7], [9], [10], [11], [12], [13], [14], [16], [17], [18], [20], [23], and [26]	16
	Financial risks and cash flows	FIN02	[5], [7], [9], [12], [13], [15], [16], [17], [18], and [27]	10
	Resource limitation and high investment	FIN03	[4], [5], [7], [9], 14], [15], [18], and [26]	8
	Contracts and risk sharing agreements	FIN04	[1], [3], [11], [13], [14], [17], and [23]	7
Technological (TEC)	Lack of technology, skills and understanding	TEC01	[4], [7], [9], [14], [18], [22], and [26]	7
	Systems for collaboration	TEC02	[3], [4], [9], [14], and [24]	5
	Systems for data collection and management	TEC03	[1], [3], [9], [18], and [21]	5
	Risks related to data and technology	TEC04	[3], [9], [13], and [26]	4
	Technology high complexity	TEC05	[9], [12], and [26]	3
	Technology strategy	TEC06	[9], [18], and [26]	3
Supply Chain (SC)	Changing relationships and governance	SC01	[1], [2], [4], [8], [9], [10], [11], [12], [13],	16

			[15], [18], [19], [21], [22], [24], and [28]	
	Collaboration and information sharing	SC02	[1], [4], [5], [8], [9], [14], [15], [17], [18], [21], [22], [24], [26], [27], and [29]	15
	Complex network and power balance	SC03	[6], [11], [12], [13], [14], [15], [18], [19], [21], [22], [24], and [28]	12
	Partners competencies, maturity, training, and awareness	SC04	[1], [3], [8], [9], [10], [17], and [22]	7
	Integration with different actors	SC05	[5], [6], [10], [12], [18], and [22]	6
	Lack of control of partner performance and reputational damage	SC06	[8], [10], [19], and [27]	4
Business Context (BUS)	Recognition of market demand and acceptance	BUS01	[4], [5], [6], [7], [9], [11], [13], [14], [15], [17], [18], [19], [23], and [24]	14
	Customer awareness and mindset	BUS02	[1], [4], [5], [10], [14], [15], [17], [21], and [27]	9
	Regulations	BUS03	[5], [8], [9], [15], [17], and [26]	6
	Economic changes	BUS04	[5], [15], and [17]	3
	Competitive environment	BUS05	[5], [7], and [24]	3
	Country specific	BUS06	[13], [15], and [27]	3
Environment (ENV)	Environmental challenges	ENV01	[4], [5], [7], [15], and [30]	5

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From Table 1, it is possible to recognize the most popular topics from the selected articles, which may be a first indicator of the relevance of the barriers. The topics mentioned

by ten or more articles are: Design of offer and portfolio; Development and/or buy new competencies; Support and service delivery; Culture shift, resistance/fear, and awareness; Profitability and pricing; Changing relationships and Governance; Collaboration and information sharing; Complex network and power balance; and Recognition of market demand and acceptance.

Each subtopic presented in Table 1 is further examined in the following sessions. The goal is to provide additional details, to facilitate the comprehension of the barriers. Some challenges are presented in more detail than others. That is mainly due to more examples found in the literature. Moreover, it is important to mention that the following session does not aim to provide solutions for the barriers collected, even if some recommendations are given in some cases.

2.3.1 Strategic challenges (STR)

Strategic challenges include nine subcategories: design of offer and portfolio; development and/or buy new competencies; access to strategic relationships and/or information; focus and image; management commitment, competencies, and resources; changing/complex business models and methods; lack of vision and understanding; strategic risks and risk management; and servitized offer cannibalizing physical products.

2.3.1.1 Design of offer and portfolio (STR01)

When designing the servitized offering and portfolio, firms may face several difficulties, such as lack of competencies for the design of services, poor customer understanding, knowledge sharing barriers, conflicts between physical attributes and service delivery, and problems in aligning the servitized portfolio with the company's overall strategy.

Indeed, it can be challenging to integrate technical, buyer and functional expertise to design and deliver product-service packages (KREYE; VAN DONK, 2021). The design of services, for instance, can be considerably challenging for manufacturers, as it is quite different from the design of products (BAINES et al., 2009), generating difficulties in the creation of service packages (HOU; NEELY, 2013).

Moreover, if the company has few internal competencies, underdeveloped service-focused knowledge structures (BIGDELI et al., 2021), lacks service design methods and integration capabilities (ALGHISI; SACCANI, 2015), and has undervalued and unclear design

practices (PACHECO et al., 2019), it may create low-quality services with basic features and limited usefulness.

For instance, a successful design may be hindered by knowledge sharing barriers between cross-functional design teams (BERTONI; LARSSON, 2011), lack of shared understanding between the many actors involved in the development process (NUDURUPATI et al., 2016), and conflicts between product and service functions over service designs (BIGDELI et al., 2021).

Besides that, unsuccessful design of value propositions may originate from a poor understanding over the customers' demands and perspectives (BANERJI; ZHANG, 2017; BIGDELI et al., 2021), as well as challenges in following continuous changes in customer needs and expectations (BERTONI; LARSSON, 2011), and hidden requirements in product use phase (PACHECO et al., 2019).

Other challenges include potential conflicts of design attributes and service delivery (PACHECO et al., 2019). For example, physical products may present limited serviceability, if it is impossible to disassemble them for cleaning (KREYE; VAN DONK, 2021) and repairing. In that case, the company may opt to redesign the product to enable digital services. However, redesigning also involves additional complexity (PURVIS et al., 2021), as there may be difficulties in integrating digital features into existing offerings and processes (LE-DAIN et al., 2023).

Besides issues in designing the servitized offering, firms may face difficulties in aligning the servitized portfolio with the company's overall strategy (ALGHISI; SACCANI, 2015) and building a balanced portfolio in terms of risk. In that case, firms must evaluate the integration of the new offering's whole life-cycle into their planning and operational activities (SPINLER; WERNING, 2020). It is also necessary to consider their risk appetite, as risk exposure increases because of the complexity and the long life-cycle of servitized offerings (JOHNSON; MENA, 2008).

To address some of the challenges mentioned, BANERJI; ZHANG, 2017 argue that the development process for a servitized offering should be a priority if the existing processes are not adequate, and additional set of tools, methods, and techniques are underdeveloped. Indeed, service design methods can be adopted, to improve flexibility, resources utilization and reduce the complexity in delivering product-service offerings.

2.3.1.2 Development and/or buy new competencies (STR02)

Firms entering the domain of Product-Service Systems (PSS) may have to acquire new capabilities, resources (PARIDA; REIM; SJODIN, 2016), and experiences, which are relevant to both management and design activities (VEZZOLI et al., 2015). Companies may develop such competencies internally or rely on external actors, compensating for missing capabilities with a broader network of partners (NUDURUPATI et al., 2016).

New required capabilities may include systems integration competencies, consultancy, financial expertise (CHAKKOL et al., 2014), digital skills, competencies for the service sector (WEERABAHU et al., 2022), knowledge about physical components and analytics capabilities (MOSCH; SCHWEIKL; OBERMAIER, 2021). In this context, companies must decide whether to develop new skills in-house or source them externally, through partnerships (ALGHISI; SACCANI, 2015; BIGDELI et al., 2018; BIGDELI et al., 2021).

The in-house versus outsource decision is not trivial and presents pros and cons for each competency. In the case of service delivery, for instance, BAINES; LIGHTFOOT; SMART, 2011 highlight the benefits of bringing this competency in-house, emphasizing improved use of maintenance staff and reduced inventory costs. However, the author recognizes that this approach requires more investment in management and resources, potentially affecting overall service costs. In addition, the insourcing of activities may not be feasible, as explained by HOWARD; LEWIS, 2009. The authors provide an example where a company chose outsourcing due to a lack of service support capabilities.

2.3.1.3 Access to strategic relationships and/or information (STR03)

Companies may have to partner with several actors to gain the required competencies to offer a DPSS, as well as partner with external actors to access strategic relationships and gather critical information. Indeed, providers of DPSSs may have alliances and collaborations with universities, suppliers, customers, and even competitors. These collaborative partnerships are important for companies to gather critical information, mitigate external dependencies, navigate complexities, and address uncertainties inherent to digital servitization (WEERABAHU et al., 2022).

After setting alliances, companies must manage their connections, guaranteeing access to strategic knowledge. For instance, strategic information comes from controlling end-user data, which has an important effect on supply chain dynamics, particularly in the context of digital servitization (MOSCH; SCHWEIKL; OBERMAIER, 2021).

Indeed, establishing relationships with customers is important for providers of DPSSs. For instance, BIGDELI et al., 2018's work underscores the challenges faced by upstream firms characterized by an inherent absence of close end-user relationships, rendering them less capable of capturing value within the digital servitization landscape.

Besides relationships dynamics, companies may lack access to important information because of internal values and procedures. For instance, ROBINSON et al., 2016 shed light on the influence of an organization's existing procurement practices on its information access. The firm under research had a procurement practice favoring the lowest-price bids, potentially discouraging suppliers from sharing critical technical knowledge, which was needed for the implementation of advanced services.

2.3.1.4 Focus and image (STR04)

In the realm of digital servitization, companies face obstacles tied to transitions in mindset (focus), image, and reputation. The mindset transition refers to a shift from the adoption of product-centric to service-centered focus, both internally and by the customers. The image and reputation transitions are linked to the firms' credibility, affected by the provision of new offerings.

The necessity of a fundamental shift in corporate mindset from a product-centric to a service-centered is well-recognized in the literature (BAINES et al., 2009; PACHECO et al., 2019; CHAKKOL et al., 2014). This shift is crucial for companies to embrace services as an integral part of their operations, prioritizing service development over traditional sources of competitive advantage, and promoting organizational change. However, in industries characterized by a traditional product-centric mindset, like the truck industry, promoting associated services becomes a notable challenge (CHAKKOL et al., 2014).

Besides the company's mindset, its image and reputation are a central aspect to be considered, as firms may find challenges in establishing themselves as credible service providers. Indeed, customers and external partners may be skeptical regarding the manufacturer's service capabilities (BIGDELI et al., 2021). Moreover, companies' fear undermining their image due to service quality issues (AHVENNIEMI; MARTINSUO; NENONEN, 2014), or diluting their brand identity, as they seek to harness digital technology (LE-DAIN et al., 2023).

These barriers are connected to strategic considerations, such as brand and reputation management. Understanding and addressing these challenges are pivotal for companies seeking to navigate the complexities of digital servitization successfully.

2.3.1.5 Management commitment, competencies, and resources (STR05)

The management of firms highly influence the successful implementation of digital servitization. The investigated literature highlights the management commitment, competencies and resources as factors hindering or promoting the adoption of the new business model.

Poor service culture and insufficient support from decision-makers hinder the development and adoption of service-oriented strategies (KAMAL et al., 2020), especially during the initial stages of implementation of service-oriented business models (PACHECO et al., 2019). Indeed, the limited commitment of top managers and key decision-makers to services is an obstacle, resulting in constrained investments in this domain (ALGHISI; SACCANI, 2015).

Moreover, the lack of social competencies in leadership positions and the absence of dedicated leaders can hinder the transition (PACHECO et al., 2019) towards digital servitization. Therefore, it is essential to have a strong internal leadership in driving the new strategy (LE-DAIN et al., 2023), by influencing the company's mindset and allocating resources and capabilities toward product-service design and innovation.

2.3.1.6 Changing/complex business models and methods (STR06)

Modifying the company's business model requires significant attention. This is a crucial aspect of the transition to digital servitization, as integrating service strategy with the production system necessitates significant changes and adjustments (BANERJI; ZHANG, 2017). Additionally, it is important to consider the transformative impact of new technologies on firms' strategies and business models (BIGDELI et al., 2018).

Thus, a main internal barrier for companies lies in the complexity of adopting the new business model, which proves to be more intricate to manage than the traditional practice of delivering only products (VEZZOLI et al., 2015). To handle the additional complexity, companies need to rely on formalized models and methods.

Therefore, it is evident that the lack of models and methods supporting the transition towards digital servitization is a critical challenge for organizations. The absence of a clear

business strategy, internal formal processes (PACHECO et al., 2019), and a cohesive ecosystem of internal and external actors can hinder the success of the strategy.

2.3.1.7 Lack of vision and understanding (STR07)

The effective adoption of services and technology face difficulties stemming from a lack of vision and understanding, which encompass issues of expertise, innovation ability (HOU; NEELY, 2013), comprehension of technology and communication barriers. Such problems may involve from field workers to the high management, whose lack of vision and understanding prevents the company from achieving the potential benefits from digital servitization.

The lack of understanding of technology and its application in the business over the long term constitutes a pivotal strategic barrier to its adoption (LE-DAIN et al., 2023). Moreover, the absence of effective communication and understanding between employees (BANERJI; ZHANG, 2017) can harm the provision of the servitized offering. For instance, employees in manufacturing companies may fully comprehend product concepts, but may lack understanding of service offerings (BAINES et al., 2009).

Besides that, the lack of vision and understanding make it difficult for managers and decision-makers to evaluate the benefits expected from the implementation of advanced product-service offerings, and to mitigate inherent risk associated with incremental and radical innovations (BIGDELI et al., 2018).

2.3.1.8 Strategic risks and risk management (STR08)

Strategic risks, such as decline in competitiveness, reputational issues (BIGDELI et al., 2018), technology integration risks, customer acceptance, data privacy and compliance, supplier and partner risks, strategic alignment, among others, pose difficulties for companies and require adept risk management. Indeed, the inability to effectively manage risks serves as a substantial impediment to the successful implementation of PSS (PARIDA; REIM; SJODIN, 2016).

In this subtopic some of the strategic risks faced by companies implementing digital servitization and management practices are briefly discussed. The goal, however, is not to create an exhaustive list, especially because different risks are analyzed in other subtopics.

Technology integration risks include compatibility issues, cybersecurity threats, and the need for continuous updates and maintenance. Risk management involves thorough assessment

of technology providers, robust cybersecurity measures, and agile development practices to adapt to changing technological landscapes.

Customer acceptance risks are related to shifting from product-centric to service-centric offerings. Strategic risks include resistance to change, dissatisfaction with new service models, and challenges in delivering value. Risk management involves market research, customer feedback mechanisms, and personalized service offerings to enhance acceptance and adoption.

Data privacy and compliance risks involve concerns about privacy, data security, and regulatory compliance. Risk management includes robust data governance frameworks, compliance with relevant regulations, and transparent communication with customers regarding data usage and privacy practices.

Supplier and partner risks refer to the risks introduced by collaborating with third-party vendors and partners, such as supply chain disruptions, contractual disputes, and reputational damage. Risk management involves due diligence in selecting partners, clear contractual agreements, and contingency plans to mitigate supplier-related risks.

Strategic alignment risks include misalignment of goals, resource allocation issues, and conflicting priorities. Risk management entails regular strategic reviews, stakeholder alignment sessions, and clear communication of objectives throughout the organization.

In summary, effective risk management in the context of digital servitization involves proactive identification, assessment, and mitigation of strategic risks to capitalize on opportunities and drive sustainable growth in an increasingly digital and service-oriented economy.

2.3.1.9 Servitized offering cannibalizing physical products (STR09)

Besides the risks mentioned above, one notable barrier revolves around the risk of new offerings cannibalizing established ones, thereby challenging existing business models and profitability. This phenomenon can be exemplified by the insights provided by MOSCH; SCHWEIKL; OBERMAIER, 2021.

MOSCH; SCHWEIKL; OBERMAIER, 2021 highlighted a significant trend in the emergence of monitoring systems and predictive maintenance solutions. These innovative solutions are designed to ensure that components operate and are maintained at optimal capacity, ultimately extending the lifetime of products.

While this development is undoubtedly beneficial in terms of product durability and customer satisfaction, it poses a potential challenge to established revenue streams.

Specifically, the longer product lifetimes, resulting from technological advances, may lead to a reduction in the sales of spare parts, traditionally one of the most profitable segments of the business.

The consequence of this trend is the shrinking market size for physical products, intensifying competitive pressure within the industry. As products become more reliable and require fewer replacement parts, the economic landscape shifts.

2.3.2 Operational challenges (OPE)

Operational challenges (OPE) include eight subcategories: support and service delivery; customer collaboration and behavior; capability to communicate and sell the offer; measurement of performance and savings; internal communication and information flows; adoption of defined processes; operational risk; complexity from digitalized products and/or processes.

2.3.2.1 Support and service delivery (OPE01)

Supporting advanced services contracts and delivering service is complex. Various scholars have identified obstacles and issues related to service delivery and support in the servitization context. For instance, PARIDA; REIM; SJODIN, 2016 discuss various risks associated with service delivery, including operational risk, execution risk, capability risk, and capacity constraints.

Other difficulties include the need for rapid and effective responses to asset failures (BAINES; LIGHTFOOT; SMART, 2011), addressing dynamic and heterogeneous customer demands (HOU; NEELY, 2013), and managing demand uncertainty in service supply chains (JOHNSON; MENA, 2008).

Additionally, there are difficulties in ensuring the reliability and serviceability of products (KREYE; VAN DONK, 2021), as well as the implementation and maintenance of digital technologies (LE-DAIN et al., 2023) in companies where service support capabilities are lacking.

Moreover, the service provision performance is influenced by the critical role of service personnel. Thus, challenges are related unqualified operators (NUDURUPATI et al., 2016), and human-based performance instability, affecting long-term relationships (BANERJI; ZHANG, 2017).

Besides that, other challenges include the effective selling and delivery of service-based offerings to different market segments, inadequate service marketing and sales expertise and excessive outsourcing of service competencies (BIGDELI et al., 2021).

2.3.2.2 Customer collaboration and behavior (OPE02)

Customer collaboration and behavior presents challenges when implementing service-oriented approaches, as highlighted by multiple authors. Indeed, the adoption of a Product-Service System (PSS) business model intensifies interactions with customers, increasing the likelihood of conflicts, disagreements, and opportunistic behavior (PARIDA; REIM; SJODIN, 2016).

In this context, some of the difficulties in operations come from high machine customization, varying levels of customer involvement, the need for proactive and flexible cooperation, customers usage patterns, among others.

Authors emphasize the critical role of customer involvement in achieving service co-creation (PACHECO et al., 2019; NUDURUPATI et al., 2016), but note that this becomes more challenging with highly customized machines and a wide range of different customer needs. Machines customization hinders knowledge management practices, the deployment of technological solutions for data collection, and the achievement of a wide database (ALGHISI; SACCANI, 2015), impacting the organization's ability to understand customer and machine behavior in the field. In addition, a wide range of different customer needs adds complexity, as the company fulfills several roles (CHAKKOL et al., 2014).

Besides that, it may be challenging to gain cooperation from customers and control their behavior and usage patterns (HOU; NEELY, 2013). Indeed, some customers not only avoid cooperation but also hide important information on working conditions, do not perform regular maintenance, when they are expected to, or depend on unqualified and unskilled third-party service organizations, which directly impact the machines' down-time (OWIDA et al., 2022).

Additional issues are related to unintended and adverse customer behavior, which include less careful behavior when using a product that the customer does not own (PARIDA; REIM; SJODIN, 2016). For instance, the customer may overload the physical product, negatively impacting its condition.

Opportunistic behavior is another example of adverse behavior, which occurs when the customer tries to maximize personal benefits, regardless of providers’ efforts. For example, customers may use the machine in a careless manner, because they have an agreement with the

dealer, which will take care of all the repairs and maintenance. In this case, providing a Product-Service System (PSS) to a fresh and unfamiliar customer entails a greater degree of risk in comparison to a well-established, loyal, and long-term customer (PARIDA; REIM; SJODIN, 2016).

2.3.2.3 Capability to communicate and sell the offer (OPE03)

The capability to communicate and sell the offer needs to be developed to allow the successful adoption of digital servitization as a profitable strategy. Thus, communication strategies that clearly describe the value proposition to the customer need to be considered from the stage of design of service provision (BAINES et al., 2009).

To plainly convey the new value proposition and achieve promising selling results, the company depends on its capacity of quantifying the value created and on its sales team's culture and ability to articulate the benefits to their customers (ROBINSON et al., 2016; LE-DAIN et al., 2023). Indeed, effectively conveying value to internal and external customers is necessary for increasing awareness of the firms' service offerings (BANERJI; ZHANG, 2017).

Ineffective market messaging leaves customers unconvinced about the price they must pay for services and consequent disapproval of service charges. Such problems may be due to the sales function's inexperience in selling services or an internal misalignment between marketing, sales, and the service function (BIGDELI et al., 2021).

For instance, PACHECO et al., 2019 provides an example in which the success in sales of a service, in the form of a leasing-contract, mainly depended on the communication and convincing customers of their future savings. Another example in the context of communicating offerings is present in the work of KREYE; VAN DONK, 2021. In one of their case studies, the Director of Sales Operations of a company indicated the need to change the culture to shift from selling only products to focusing on services and selling a promise.

Therefore, the success of digital servitization depends on the company's ability to develop effective communication and selling practices. Indeed, various authors stress the vital role of articulating the value proposition to internal and external customers.

2.3.2.4 Measurement of performance and savings (OPE04)

It is imperative to measure the increment in performance or the savings customers will have if they buy the digitalized PSS, to convince them that the charge for the advanced service

is worth it. However, some authors pointed out difficulties in quantifying such benefits (HOU; NEELY, 2013; VEZZOLI et al., 2015).

Indeed NUDURUPATI et al., 2016 highlighted some important questions in this aspect, for instance: how to measure value-in-use through life? What are the metrics? Is it necessary to involve customers in evaluating the offering through life? If so, how? All these questions need to be considered by the company while designing the PSS offering.

To tackle the difficulty of quantifying the servitized offering value, BANERJI; ZHANG, 2017 explains the need for a new set of indicators for the service offerings. This is because product-focused companies' performance measurements may be exclusively focused on manufactured goods.

In conclusion, measuring benefits and convincing customers of the value of DPSS is a challenge. The complexities in quantifying these benefits, as well as the need to address questions regarding value-in-use metrics and customer involvement, emphasize the importance of thoughtful design. To address these challenges, it is important to have performance indicators for service offerings.

2.3.2.5 Internal communication and information flows (OPE05)

Companies adopting digital servitization may have difficulties in knowledge and information management (HOU; NEELY, 2013) as well as problems with monitoring/information sharing (PARIDA; REIM; SJODIN, 2016).

As explained by KREYE; VAN DONK, 2021, servitized manufacturers must manage an increased information flow, ensuring that relevant information is available at the right time. For instance, manufacturers selling the service of predictive maintenance need to have timely information about the equipment’s condition.

HOWARD; LEWIS, 2009 adds to the discussion, indicating an amplifier of the mentioned challenge: managing information exchange among different actors, who are necessary for the service provision. This poses difficulties in dealing with and sharing ‘sensitive’ information, such as customer calls, breakdowns, critical components defects, and so on.

Therefore, companies must deal with the complexity of managing information flows to provide advanced services. In some cases, firms may also have to master the intricacies of information exchange among various stakeholders.

2.3.2.6 Adoption of defines processes (OPE06)

One of the great issues in implementing a new business model is the need to adopt and manage operational changes. To tackle this challenge, firms need to create clear operational processes on the transformation path. Indeed, the lack of defined processes may result in difficulties in managing basic operations and issues to implement digital technologies (LE-DAIN et al., 2023).

In accordance, ROBINSON et al., 2016 indicates that firms must have the skills and capabilities to develop more standardized processes, to improve the reliability of their systems. According to the scholars, improvements can be accomplished through repeatable, standardized design and manufacturing processes.

BIGDELI et al., 2021 complements the discussion. An examination of their interviews' findings revealed that numerous manufacturers encountered challenges when it came to devising successful strategies for entering the services market. Examples include ineffective service marketing strategies and poorly defined processes for introducing services, and manufacturers' unfamiliarity with the service industry standards and best practices.

Therefore, companies necessitate to establish clear operational processes for successful transformation, including the creation of standardized processes, to enhance system reliability, and expertise in service industry standards and best practices.

2.3.2.7 Operational risks (OPE07)

PARIDA; REIM; SJODIN, 2016 emphasized the critical nature of operational risks in PSS provision. These risks encompass not only technical and behavioral aspects but also extend to the provider's delivery competences, including service support systems. Moreover, the authors highlight concerns related to breakdowns, capacity constraints, and logistical challenges in the context of PSS.

A significant focus in the literature explored by PARIDA; REIM; SJODIN, 2016 has been on unexpected breakdowns of products and the resulting implications, such as increased repair and maintenance costs and other associated penalties. These technical risks and malfunctions pose a substantial challenge to PSS providers, as they hinder the delivery of promised services and availability. Machine breakdown risks are a particular area of concern, when the provider is accountable for addressing unexpected breakdowns, underscoring the importance of reliable data and information.

Moreover, uncertainty regarding the performance of new or custom-made products with limited historical data further complicates the risk landscape. While standardized, high-volume products allow for a more predictable calculation of costs related to product failures and their frequency, the situation becomes more complex for new and specialized products. In such cases, sharing risks with customers, particularly when the financial impact of technical malfunctions is substantial, becomes a prudent approach.

BANERJI; ZHANG, 2017 complements the discussion, explaining the complexity of operational risks in the context of service portfolio expansion, where many uncertainties and changes emerge as companies endeavor to provide value to new business customers.

Therefore, a comprehensive understanding of operational risks is imperative for successful adoption of DPSS. To mitigate these challenges, manufacturers should employ robust data collection and analysis strategies and consider risk-sharing models with customers, particularly for novel and specialized products.

2.3.2.8 Complexity from digitalized products and/or processes (OPE08)

As manufacturers shift towards digital servitization, they are compelled to develop and deliver increasingly complex products and services. These products demand a high level of expertise and innovation to design, produce, and maintain, which can be a daunting task. This complexity adds to the overall challenges faced by manufacturers, making it essential for them to invest in research, development, and training to meet the demands of the evolving digital landscape (OWIDA et al., 2022).

For instance, emerging digital PSS providers may have to deal with complexities coming from a digital transformation, which require substantial efforts, investments, and time. In this context, the lack of convenient tools and resources are major issues (LE-DAIN et al., 2023).

Small and medium-sized enterprises may especially face complexity when adapting to new products and production trends brought about by the advent of digital technologies. This complexity can be overwhelming and necessitates careful planning and strategic adjustments to ensure a smooth transition (LE-DAIN et al., 2023).

2.3.3 Organizational challenges (ORG)

Organization challenges include four subcategories: culture shift, resistance, fear, and awareness; organizational design and knowledge management; internal conflicts and silos; training and hiring.

2.3.3.1 Culture shift, resistance, fear, and awareness (ORG01)

Several scholars emphasize the need for a cultural change within manufacturing organizations to transition from a product-centric approach to a service-oriented one, while pursuing systemic innovation (VEZZOLI et al., 2015) and servitization (ALGHISI; SACCANI, 2015; BAINES et al., 2009; CHAKKOL et al., 2014; HOU; NEELY, 2013; KAMAL et al., 2020; AHVENNIEMI; MARTINSUO; NENONEN, 2014; BANERJI; ZHANG, 2017).

A paradigm shift is necessary to create an outcome-driven culture, where manufacturing and service activities are not delineated but integrated, being essential to develop behaviors that align with this integrated approach (NUDURUPATI et al., 2016). Indeed, manufacturers must confront cultural and organizational resistance in a transformation that implies a shift in the mindset of both employees and the organization itself, aligning the servitization strategy with the corporate culture to address challenges effectively.

As explained by HOU; NEELY, 2013, the resistance to change, especially in building service-oriented organizational structures, may stem from the deep-rooted focus on efficiency and economy of scale, which makes it challenging to shift to a service-oriented mindset. To tackle this resistance, it is imperative to educate and develop the competencies of the employees, such as the sales force (CHAKKOL et al., 2014), who must place customer satisfaction at the center of attention (PACHECO et al., 2019) and focus on selling not just products but promises of service (KREYE; VAN DONK, 2021).

Besides the difficulty in transitioning to a service-oriented mindset, LE-DAIN et al., 2023 point out that reluctance to assimilate digital technologies and the lack of digital culture also pose significant barriers to the adoption of digital servitization. Rigid and inflexible mindsets and concerns about job displacement by machines further hinder this transformation. Aligned with this, WEERABAHU et al., 2022 emphasize the need for a digital service-oriented organizational culture and training to enable digital servitization.

Therefore, manufacturers pursuing the path of digital servitization encounter the need for cultural change, in a shift from a product-centric to a digital service-centric mindset.

Overcoming the intrinsic resistance of employees and the company itself is imperative, to succeed in implementing digital servitization.

2.3.3.2 Organizational design and knowledge management (ORG02)

Digital servitization often involves the redeployment and reconfiguration of a company's resource base and organizational capabilities and structures. This entails a redefinition of the firm's mission and a revamping of routines and shared norms and values (PURVIS et al., 2021), as well as changes in infrastructure, resources, and knowledge capturing and management (NUDURUPATI et al., 2016).

In this way, the lack of service-based organizational structures as well as difficulties in knowledge and information management can hinder the development of effective service (HOU; NEELY, 2013) and digital strategies. Indeed, ALGHISI; SACCANI, 2015 emphasize that the success of digital servitization hinges on substantial organizational changes in language, values, design processes, and overall design.

BIGDELI et al., 2021 reinforce the need for creating new service organizations responsible for service-related activities, which can disrupt established organizational structures. The shift toward relationship-based value creation necessitates an increased number of employees interacting directly with customers, resulting in a reorientation of roles that manufacturers must grapple with.

Furthermore, ALGHISI; SACCANI, 2015 stress the importance of internal cooperation among different organizational units involved in service development, delivery, and customer relationships. This internal collaboration is critical for delivering integrated and customer-centric services. Aligned with that, KAMAL et al., 2020 underscore the need for improved cross-functional cooperation within manufacturers when implementing digital servitization. This level of internal collaboration is essential to deliver highly complex offerings, such as performance-based agreements.

In conclusion, firms need to prepare for organizational changes, knowledge management, structural adjustments, and enhanced cooperation among various organizational units. Embracing advanced services and navigating the complexities of service-centric networks are also pivotal in this transformation.

2.3.3.3 Internal conflicts and silos (ORG03)

Within a company, the change of emphasis from manufacturing to services can cause internal conflicts between different sectors (HOU; NEELY, 2013), such as conflicts between sales and service (PACHECO et al., 2019). Moreover, manufacturing sectors may be unwilling to lose authority and resources, leading to the increase of political costs (HOU; NEELY, 2013).

The conflicts can lead to a compartmentalized organization (silo organization), that slows communication (LE-DAIN et al., 2023), prevent close collaboration, augment the absence of an internal common language and alignment of mindsets (VEZZOLI et al., 2015). To exemplify, BIGDELI et al., 2021 investigate cases in which there are disagreements across various functions over service-related opportunities resulting in non-cooperative silos

That is a considerable issue, as improved inter-departmental information-sharing and joint decision-making are needed in companies moving towards digital servitization, to smooth the flow of resources (WEERABAHU et al., 2022). Moreover, intra-organizational synergy is necessary to support the development and delivery of integrated offerings (BANERJI; ZHANG, 2017).

However, with product and service teams been managed separately in the past, companies may find it difficult to reconfigure their organizational structure and overcome the problem of silos (BANERJI; ZHANG, 2017).

2.3.3.4 Training and hiring (ORG04)

The performance of service offerings is heavily reliant on the skills and expertise of service personnel, with their specializations directly influencing customer satisfaction in service delivery (BANERJI; ZHANG, 2017). In this way, continuous training employees, personnel management, and hiring professional service specialists are essential aspects to consider for companies pursuing digital servitization (OWIDA et al., 2022; VEZZOLI et al., 2015; BANERJI; ZHANG, 2017).

It is imperative to educate and develop the competencies of the employees, such as the sales force (CHAKKOL et al., 2014), who must place customer satisfaction at the center of attention (PACHECO et al., 2019) and focus on selling not just products but promises of service (KREYE; VAN DONK, 2021).

Moreover, employees need to be prepared to adapt to new offerings and the advent of digital technologies. Training needs to prepare the workforce to deal with new requirements,

such as a high level of expertise and innovation to design, produce, and maintain digital PSS offerings. BANERJI; ZHANG, 2017's work adds to the discussion, highlighting the pivotal role of acquiring and retaining professional service specialists in this journey. They stress that the growth of services in manufacturing companies is intrinsically linked to the presence of such specialists.

In conclusion, the challenges faced by firms include continuous training, effectively managing personnel, and strategic incorporating professional service specialists.

2.3.4 Financial challenges (FIN)

Financial challenges include four subcategories: profitability and pricing; financial risks and cash flows; resource limitation and high investment; contracts and risk sharing agreements.

2.3.4.1 Profitability and pricing (FIN01)

Firms must face concerns regarding pricing competence and the economic benefits of the new product-service system-oriented business model (WEERABAHU et al., 2022). Indeed, emerging digital PSS providers need to establish the right price to cover risks, attract and retain customers at the same time. However, pricing a servitized offering can be complex, due to the uncertainty associated with the nature of services (NUDURUPATI et al., 2016).

Besides pricing, there might be profitability issues. In terms of revenues, some authors argue that, despite substantial investments, returns may not meet the expectations (KAMAL et al., 2020), leading to unsatisfactory economic outcomes (HOWARD; LEWIS, 2009). Additionally, there are risks associated with the complexity and unpredictability of costs. For instance, BIGDELI et al., 2018 highlight cost risks when implementing outcome-based contracts, especially in large-scale operations with low margins.

Overcoming the mentioned challenges is essential for companies aiming to transition successfully to a service-oriented business model. It is imperative to comprehend the cost structure of the new business model in the context of digital servitization (PURVIS et al., 2021), the revenue sources and adopt an adequate pricing strategy.

2.3.4.2 Financial risks and cash flows (FIN02)

The path towards digital servitization may incur financial risks and unexpected costs. Indeed VEZZOLI et al., 2015 note that service-product system business models demand

medium to long-term investments, leading to uncertainties about cash flows and a perception of higher risk compared to product-based models.

In the same way, SPINLER; WERNING, 2020 highlight that the unpredictable cash flow, revenue, and cost developments associated with servitization make it a risky proposition for manufacturers. To exemplify, some financial risks include direct negative impacts on profit, revenue, and market share (BIGDELI et al., 2018), financial loss when not delivering services as agreed (PARIDA; SJODIN; REIM, 2016) and delayed payments by customers (OWIDA et al., 2022).

To successfully navigate digital servitization, manufacturers must minimize exposure to high-risk scenarios with a structured approach. Commencing with a meticulous risk assessment, the identification and prioritization of risks is a fundamental step. Tailoring a bespoke risk mitigation strategy is imperative, which encompasses options such as risk avoidance, reduction, transfer, or acceptance contingent upon the nuanced attributes of each risk.

Moreover, as explained by PARIDA; SJODIN; REIM, 2016, effective contract management helps in handling the complexity that arises from sharing or transferring risks. Contracts play a pivotal role in risk mitigation, but the percentages on which risk sharing is based must be carefully determined to make it an attractive option.

2.3.4.3 Resource limitation and high investment (FIN03)

Companies may encounter limitation of financial resources, hindering their ability to pursue digital servitization effectively (PACHECO et al., 2019). This financial constraint, particularly plagues SMEs, which often struggle to finance innovative business models due to their inherently limited financial resources (VEZZOLI et al., 2015).

Indeed, SMEs face challenges in securing financial resources for digital servitization. These smaller entities often encounter difficulties in bearing the costs associated with developing the skills and resources required for the servitization process (LE-DAIN et al., 2023). Moreover, project budgets are often constrained, leading to decisions that may sacrifice essential elements, such as sensors, in favor of cost control (ROBINSON et al., 2016), which compromises the ability to monitor product performance effectively.

The challenge of limited financial resources also extends to the implementation of Industry 4.0 technologies (WEERABAHU et al., 2022), due to the lack of funds for acquiring appropriate tools. Moreover, besides the investments to reach Industry 4.0 objectives and build

the required infrastructure, there is also the need for investing in research and development programs to develop people and processes for digital servitization.

2.3.4.4 Contracts and risk sharing agreements (FIN04)

The combination of product and service offerings requires organizations to fulfill diverse contractual obligations. This leads to a redistribution of risks and incentives between the parties involved, necessitating the development of risk-pooling capacity and appropriate contract models (NUDURUPATI et al., 2016).

Moreover, organizations must decide whether to transfer or retain ownership of products in their service contracts (HOWARD; LEWIS, 2009). Identifying the optimal contracting approach, such as leasing, renting, or performance-based contracts, is a critical challenge. Thus, companies must explore different risks and incentives involved in these approaches and develop strategies for equitable risk distribution.

Indeed, the adoption of digital servitization introduces various complexities related to risk management, contractual obligations, and collaboration with customers. For instance, by offering full-risk maintenance contracts, firms are exposed to substantial financial and operational risks (ALGHISI; SACCANI, 2015). The risk exposure can be a formidable challenge, as it may affect the financial stability of the organization.

BAINES; LIGHTFOOT; SMART, 2011 highlight another challenge: penalties for failing to deliver against services contracts. Manufacturers need to meet diverse and unpredictable customer requirements while also ensuring economic feasibility. Failure to deliver on these contracts can result in financial penalties, further complicating the transition to digital servitization.

Besides contracts with customers, BANERJI; ZHANG, 2017 underscore the need for agreements on risk-sharing among supply chain partners in the context of intangible services. The inherent uncertainties associated with service offerings require careful negotiation and collaboration to ensure successful risk-sharing arrangements.

2.3.5 Technological challenges (TEC)

Technological challenges include six subcategories: lack of technology, skills and understanding; systems for collaboration; systems for data collection and management; risks related to data and technology; technology high complexity; technology strategy.

2.3.5.1 Lack of technology, skills, and understanding (TEC01)

Companies adopting digital servitization can face problems related to the lack of skills and understanding (e.g., digital expertise), the absence of infrastructure and technological capacity, as well as financial limits that inhibit adoption of recent technologies (LE-DAIN et al., 2023).

For instance, many small and medium enterprises have technological problems related to their PSS offering because of the unavailability of technical resources and financial constraints to upgrade and adopt digital technologies (WEERABAHU et al., 2022).

In addition, the lack of in-house technological knowledge may be perceived as a factor that increases the risk of implementing advanced services. For example, in a case study conducted by BIGDELI et al., 2018, the risk perception about technology implementation was higher for actors that lacked the understanding on the relevant technology.

Despite that, even if the firm does not possess the competencies required to offer advanced solutions, it can rely on partners and suppliers. For instance, providers of integrated solutions can depend on the specialized skills and capabilities of their suppliers, relying on various technologies provided by them (FINNE; HOLMSTROM, 2013).

However, strong dependencies between partner companies, particularly when a company heavily relies on specialized suppliers without possessing internal knowledge, pose significant risks. That is because such dependencies expose the company to supply chain disruptions, due to issues faced by the supplier, compromise quality control, as the company lacks the ability to assess the goods or services provided, and result in increased costs, due to limited negotiation power. Moreover, a lack of internal knowledge may suppress innovation, while reliance on external partners may entail a loss of operational control.

Therefore, having technological capacity and infrastructure and a good understanding of technology are enablers of product-service offerings. Thus, some companies opt to transform their information system (LE-DAIN et al., 2023), invest in coordination and innovative research and development (WEERABAHU et al., 2022), to implement digital servitization.

2.3.5.2 Systems for collaboration (TEC02)

Knowledge-sharing is essential to succeed in digital servitization settings, both inside and outside the boundaries of the digital PSS provider. Inside the company, teams developing

new offerings require the skills and knowledge from different people in distinct physical locations. Thus, they need to establish an infrastructure that allows the transfer of knowledge and information among them (BERTONI; LARSSON, 2011).

Moreover, outside the boundaries of the company, the development of a common data sharing infrastructure is fundamental for the joint development and provision of DPSS (MOSCH; SCHWEIKL; OBERMAIER, 2021), and is an enabler of open innovation, helping firms to leverage the skills and resources embedded in their supply chain.

However, firms may face difficulties when they have a weak collaborative value network, with lack of standardized IT tools and procedures, incompatible information technologies, underdeveloped information sharing (LE-DAIN et al., 2023), and disarticulated use of Information and Communications Technology (ICT) (PACHECO et al., 2019).

To exemplify, even if a company is willing to share detailed technical information with its suppliers to gather intelligence around lifetime performance of an asset, it will not be able to do so, if the existing tools within the activity system do not permit proper information sharing (ROBINSON et al., 2016).

2.3.5.3 Systems for data collection and management (TEC03)

To provide digital product-service systems, firms must collect data from products in operation and have a structured knowledge management process, enabled by technologies embedded in the products and IT systems (ALGHISI; SACCANI, 2015). For example, in the aerospace industry, the collection, storage and management of valuable information about the causes of a failure in aircrafts can help engineers to address functioning issues and perform adequate maintenance.

However, it is not trivial to manage a huge amount of information over extended periods of time. Therefore, firms may struggle to access information, which can be too dispersed and hidden by other elements to be retrievable (BERTONI; LARSSON, 2011).

Moreover, high customization typical of ETO products can hinder knowledge management practices, preventing the deployment of technological solutions for data collection and the achievement of a wide database (ALGHISI; SACCANI, 2015).

Besides that, difficulties may arise from lack of standardized IT tools and procedures (LE-DAIN et al., 2023) and absence of required technology internally or in the market for data collection and management.

2.3.5.4 Risks related to data and technology (TEC04)

Data protection and cyber security issues are highly relevant topics, as an increased connectivity among value chain partners, involved in the digital servitization strategy (WEERABAHU et al., 2022), exposes companies to a higher risk of knowledge leakage (BERTONI; LARSSON, 2011), data breaches, data manipulation, and unsecured access to production and corporate systems (LE-DAIN et al., 2023).

As providers need deeper insights into their clients' operations to develop advanced solutions, firms selling digital PSS must implement cybersecurity protocols and govern data properly, to convince partners and customers to cooperate. However, this type of expertise often lacks in small and medium enterprises (LE-DAIN et al., 2023).

Besides cyber security, there are risks associated with the technological tools implemented, which could become quickly obsolete, becoming an expensive financial and structural burden (LE-DAIN et al., 2023; PARIDA; REIM; SJODIN, 2016).

2.3.5.5 Technology high complexity (TEC05)

Companies can use Industry 4.0 technologies, such as cloud, big data, blockchain and IoT to design and re-design their servitization business models (WEERABAHU et al., 2022).

However, obstacles may arise from the complexity of digital technologies (LE-DAIN et al., 2023), and poor assessment and testing over their applications in the servitization context, requiring a careful analysis (WEERABAHU et al., 2022).

Moreover, new disrupting technologies can make radical changes to manufacturing processes and supply chain configurations (PURVIS et al., 2021), posing challenges for firms to adapt.

2.3.5.6 Technology strategy (TEC06)

Companies adopting digital servitization may face problems related to the lack of strategic digital vision (LE-DAIN et al., 2023), and lack of understanding on its relation to developing the design of digital service packages, organizational structures, and processes (WEERABAHU et al., 2022).

Indeed, firms may over focus on daily operations and ignore the long-term vision, spending insufficient time on planning the strategy, which is necessary to make the right technology investment decisions (LE-DAIN et al., 2023), as well as right supplier partnerships.

To exemplify the importance on planning the company's strategy, a strategic technology supplier partnership can bring important economic benefits, such as economies of scope (BIGDELI et al., 2018).

2.3.6 Supply chain Challenges (SC)

Supply Chain challenges include six subcategories: changing relationships and governance; collaboration and information sharing; complex network and power balance; Partners competencies, maturity, training, and awareness; integration with different actors; Lack of control of partner performance and reputational damage.

2.3.6.1 Changing relationships and governance (SC01)

The adoption of digital servitization and digital technology can change the strategy and structure of the firm, affect partners, customers, and the firm's ecosystem network (LE-DAIN et al., 2023). Thus, companies transitioning to digital servitization may be required to re-design their supply chain processes and recalibrate supply chain interdependencies. In doing so, a redistribution of roles amongst the supply chain actors is likely to occur (PURVIS et al., 2021).

In this context, challenges may arise from: 1) new sources of competition, 2) destruction of pre-existing relationships, 3) necessity to build stronger relationships, and 4) establishment of governance mechanisms.

2.3.6.1.1 New sources of competition

New sources of competition emerge when the company, willing to offer new services, enters a market already covered by its service partners, direct customers (ALGHISI; SACCANI, 2015), suppliers, and distributors (BAINES et al., 2009). For instance, CHAKKOL et al., 2014 investigated the case of a company in the truck market, which avoided investing in the selling of services due to significant competition from third party service providers.

Besides the situation in which a firm A enters an already covered market, new competition can occur when other actors in the network make strategic moves, attempting to compete in an arena previously dominated by A. For instance, firm A's suppliers may attempt to build their own brand as a service provider, instead of having no interaction with final customers, merely supporting A in service provision.

The risk of emerging competition from suppliers increases when firms lose control to its suppliers, through outsourcing service provision (AHVENNIEMI; MARTINSUO; NENONEN, 2014).

2.3.6.1.2 Destruction of pre-existing relationships

Companies implementing digital servitization may have to redistribute tasks among the value chain actors. In some cases, firms must decide to either by-pass existing relationships between consumer and intermediaries or shape cooperation in a mutual beneficial way (KREYE; VAN DONK, 2021).

When companies decide to remove intermediaries from the service provision business, they can face some challenges. For instance, setting up a service network can be a major investment (KREYE; VAN DONK, 2021) for manufacturing companies, depending on the size of the consumer base. Moreover, intermediaries may hold customers' trust, playing an important role in their buying decisions. Thus, removing intermediaries can be costly to the company, if its customer base follows the intermediary, as it partners with a different provider.

Moreover, relationship issues may arise between suppliers and original equipment manufacturers (OEMs). Suppliers may equip their components with sensors or devices for collecting data and deliver services directly to end-users. This strategy, however, excludes OEMs from service provision and challenges their power position, potentially resulting in conflicts between suppliers and OEMs (MOSCH; SCHWEIKL; OBERMAIER, 2021).

2.3.6.1.3 Necessity to build stronger relationships

Digital servitization may require stronger relationships between companies and its customers, suppliers, and other key players (BIGDELI et al., 2021). Indeed, there is a need to replace the value of exchange by value in use involving long-term relationships (PACHECO et al., 2019).

For instance, MOSCH; SCHWEIKL; OBERMAIER, 2021's investigation of the literature shows a case in which the adoption of IoT-based solutions drew original equipment manufacturers and its end-users (operators) closer via increasing trust, mutual specific investments, and risk sharing.

However, by setting stronger bonds, through partnerships and entrepreneurial interdependence, companies may have reduced control on their core competencies, lower influence on business decisions (VEZZOLI et al., 2015), and high switching costs, being locked into the relationship (MOSCH; SCHWEIKL; OBERMAIER, 2021). In addition, deep

collaborations bring complexity when companies must manage multi-year partnerships and long-term risk and exposure (ALGHISI; SACCANI, 2015).

Moreover, this closer cooperation with customers and partners may increase the pressure on the company to perform. For example, if the firm provides a service which was previously controlled by customers, it must live up to the expectations, to avoid harming the relationship (AHVENNIEMI; MARTINSUO; NENONEN, 2014).

2.3.6.1.4 Establishment of governance mechanisms

As advanced services change the relationship between customer, provider, and network partners significantly, firms need to adopt new organizational structures and governance mechanisms (BIGDELI et al., 2018). This helps to understand the high importance of network coordination for servitization (AHVENNIEMI; MARTINSUO; NENONEN, 2014). Indeed, relationship governance has received much attention in the B2B servitization literature (KREYE; VAN DONK, 2021).

The changed business relationships between provider and customer need governance, with proper coordination and control mechanisms, which may be difficult to implement. Such mechanisms depend on the type of relationship. For instance, in B2B service relationships, providers often rely on relational coordination mechanisms due to the long-term and close relationships with the customer (KREYE; VAN DONK, 2021).

2.3.6.2 Collaboration and information sharing (SC02)

In the context of digital servitization, greater degree of integration among the actors is required, involving increased information exchange (ALGHISI; SACCANI, 2015). Indeed, value chain visibility is a prerequisite to implementing advanced services (BIGDELI et al., 2018). Moreover, firms should have collaborative relationships with their network partners to co-create superior value, as service is best deployed through closer relationships (CHAKKOL et al., 2014).

To exemplify, CHAKKOL et al., 2014's study indicated that a great level of coordination and sharing of information between the company under analysis, its dealers, technical suppliers, and customers was required to provide adequate support and advanced telematics service.

However, despite the need for stronger collaboration between stakeholders, there is often lack of information from several tiers in the supply chain, which makes the provision of advanced services difficult. To exemplify, suppliers may have little visibility of the clients'

actual consumption over its life cycle (PEREIRA; QUEIROZ; REBELO, 2022). This hinders the offering of services, as accessing customer operational data sometimes is essential for service operators to do the job properly (BANERJI; ZHANG, 2017).

The lack of information can have several reasons, such as lack of trust and fear of data leakage. Indeed, the fear of sharing sensitive information about companies' processes, products and technologies is a barrier for the deployment of digital servitization (VEZZOLI et al., 2015). Therefore, companies must maintain transparency and build trust with its customers and partners to favor data exchange (WEERABAHU et al., 2022).

Besides that, the unwillingness to share data can also occur when the parties involved in the provision of the service traditionally see each other as competitors in providing services (FINNE; HOLMSTROM, 2013), or fear losing intellectual property by digital technology through the cloud (LE-DAIN et al., 2023). In the first case, it would be hard to get coordination and cooperation from the different actors. In the second case, cyber security protocols implementation could convince the firms to share information.

2.3.6.3 Complex network and power balance (SC03)

As mentioned, transitioning to digital servitization may require firms to re-design their supply chain and recalibrate supply chain interdependencies. By doing so, companies may deal with increasingly complex supply chains and different power dynamics between actors, with an impact on the upstream–downstream power structure.

2.3.6.3.1 Complex network

In the context of digital servitization, managing several product and service components across multiple suppliers and customers can be difficult, costly, and complex (ROBINSON et al., 2016). Such complexity rises as the number of actors increases (CHAKKOL et al., 2014) and is necessary to deal with a wide range of different business interests and a varying ability to provide required services (FINNE; HOLMSTROM, 2013).

Indeed, as explained by JOHNSON; MENA, 2008, the deployment of servitization integrates multiple organizational functions and actors and is altogether complicated. In many cases, effective servitization requires the coordination of many systems, such as manufacturing, maintenance, spare parts supply, and logistics. Moreover, services and support may be provided by different members of the supply network.

Thus, with the incurring levels of increased complexity, the importance of supply chain transparency and accurate coordination of activities is extremely relevant (PURVIS et al.,

2021). Moreover, strategic partner management is one of the critical success factors for the deployment (VEZZOLI et al., 2015) of digital PSS offerings.

2.3.6.3.2 Power balance

Some authors argue that the addition of digital services in product firms increases the relative dependence of upstream firms on downstream companies. That is because the downstream positioning, closer to the final customers, yields opportunities from gathering and analyzing large volumes of consumer data. Thus, there may be a process of downstream empowerment, generating asymmetric interdependencies in processes of digital servitization (VENDRELL-HERRERO et al., 2017).

However, other authors argue that the empowerment process depends on the pre-existent power structure before the adoption of digital servitization. Therefore, they state that the power asymmetry may also occur in the opposite direction, with upstream firms increasing their influence (MOSCH; SCHWEIKL; OBERMAIER, 2021).

In any case, firms should seek to deploy unique resources, to cope with the power movements and ensure that their strategic position in the supply chain is not diminished. For instance, even if downstream firms gain control of link channels to consumers, upstream companies can regain power by possessing key resources, desirable to the consumer (VENDRELL-HERRERO et al., 2017).

2.3.6.4 Partners competencies, maturity, training, and awareness (SC04)

Network choices regarding partner selection, training, relationship governance and joint marketing to consumers shape servitization (KREYE; VAN DONK, 2021). Thus, the successful deployment of digital servitization offerings may hinge on the competencies, maturity, training, and awareness of the partners involved.

For instance, partners may have to possess digital maturity and understanding of the digital technologies, to contribute on the creation and provision value-added offerings. This may include competencies in areas such as data analytics, cloud computing, cybersecurity, and Internet of Things (IoT).

Besides technical competencies, cultural readiness is a requirement for service network partners. For example, selling problems may emerge if the service network is skeptical about the provision of advanced after-sales services (ALGHISI; SACCANI, 2015).

Partners also need to demonstrate maturity in their approach to innovation and collaboration, as digital servitization often requires a significant shift in business models and

organizational structures. Indeed, the shift of mindset goes beyond the focal company, being also necessary in the supply chain partners, as supplying physical goods and servitized offerings are different (BANERJI; ZHANG, 2017).

Therefore, service network partners involved in service delivery must be adequately trained to promote the service offer (ALGHISI; SACCANI, 2015). Comprehensive training programs are crucial for ensuring that partners have the necessary skills and knowledge. This includes understanding the needs and expectations of customers, as well as how to effectively market and sell digital servitization offerings.

In a case investigated by AHVENNIEMI; MARTINSUO; NENONEN, 2014, the managers emphasized the importance of installation group training, especially with respect to behavior, as the key component of the supplier network coordination in their field. This highlights the need for closer relationships and engagement in training activities also closer control (KREYE; VAN DONK, 2021) over partners and suppliers.

2.3.6.5 Integration with different actors (SC05)

To offer DPSS, companies can take a SC perspective, accessing the required capabilities in the wider network of partners. Thus, it is not crucial for firms to have all the competencies in-house to provide services (PURVIS et al., 2021).

However, integrating different actors in the supply chain can be costly and time consuming. Different companies may be afraid of losing their key competitive capabilities to each other, which is a barrier to introducing collaborative relationships (FINNE; HOLMSTROM, 2013).

Moreover, manufacturing firms may find challenging to cooperate with third parties for service provision. That is because of the divergent nature of services compared with goods and the supply networks for the provision of products and services (AHVENNIEMI; MARTINSUO; NENONEN, 2014).

Thus, the literature highlights the Importance of selecting the right partner, especially considering the high percentage of failed partnerships (BIGDELI et al., 2018).

2.3.6.6 Lack of control of partner performance and reputational damage (SC06)

When collaborating with different actors, firms need to select partners whose performance is aligned with its clients' expectations, and proceed with quality control, to avoid reputational

and image risks. For instance, problems may be caused by third parties' poor quality service delivery, inappropriate communication and behavior, and delays.

To exemplify, external workers may operate at the customer interface under the servitizing company's brand, with little control. In this case, the external workers have a significant effect on customers' experiences and the quality of their performance plays a major role in the servitizing company's image (AHVENNIEMI; MARTINSUO; NENONEN, 2014).

Therefore, to ensure the delivery of high service quality and have full control on the process, some companies prefer not to provide the service through external parties (OWIDA et al., 2022). In this way, they also avoid difficulties in building and controlling external partner collaborations (BIGDELI et al., 2021).

2.3.7 Business context challenges (BUS)

Business context challenges (BUS) include six subcategories: recognition of market demand and market acceptance; customer awareness and mindset; regulations; economic changes; competitive environment; country specific.

2.3.7.1 Recognition of market demand and acceptance (BUS01)

Several scholars view the lack of recognition and understanding of market demand as a difficulty to the companies implementing servitized offerings (PACHECO et al., 2019; HOU; NEELY, 2013; HOWARD; LEWIS, 2009). Indeed, to develop a digital PSS, manufacturers need to understand end-customer markets, and be conscious of how and in which conditions their product is going to be used (MOSCH; SCHWEIKL; OBERMAIER, 2021). That is because a successful PSS design requires a deep understanding of the interactions of the clients with the offering over its lifecycle, including behavioral, cultural, and mechanical factors (NUDURUPATI et al., 2016).

When the firm fails to adopt a service- and customer-centric logic, with poor understanding of how customers experience value, it faces problems to create attractive offerings. To exemplify, in a case investigated by BIGDELI et al., 2021, the lack of manufacturers' knowledge on customers' requirements and pain points prevented them from developing more attractive service offerings and building their service business.

Besides the lack of understanding of customers' needs, a related barrier is the uncertainty of market's acceptance of the proposed servitization (LE-DAIN et al., 2023 and PARIDA; REIM; SJODIN, 2016). The reluctance in accepting and adopting these novel

systems may be due to pre-existing habits, a poor perception over the service provider, financial reasons or other factors that make users feel unsure, especially when the offering implicates a radical change (VEZZOLI et al., 2015).

Therefore, it is important form companies to develop a profound understanding of the user, its attitudes and values, lifestyles and habits, and behaviors and motivations (VEZZOLI et al., 2015). The firms may also communicate the idea to customers first and then explore the requirements of the offerings, to guarantee a match with the customer needs (BANERJI; ZHANG, 2017).

2.3.7.2 Customer awareness and mindset (BUS02)

In the context of servitization, customers need to change their mindset, to better understand the value of servitized offerings and to move from the ownership to the access paradigm (ALGHISI; SACCANI, 2015). However, the cultural shift necessary to value an ownerless way of having a satisfaction fulfilled, as opposed to owning the product, is a main barrier (VEZZOLI et al., 2015).

Indeed, in the work of OWIDA et al., 2022, customer mindset and a lack of awareness was among the main challenges and risks that internationalized manufacturers faced in Egypt, being present in twelve cases studied by the scholars. This challenge was significant for capital goods industry cases, which had negative impacts in the implementation of repair services.

Despite the need to change customers' mindset, it can be challenging. In the context of B2C PSS offerings, for instance, some people may rather the ownership of physical goods, as accumulation of products may be perceived as a measure of success, indicating a certain position in society. In addition, hesitation towards shared based offerings can be linked to the perception of independence, hygiene and intimacy usually connected to one's own products (VEZZOLI et al., 2015).

Besides the willingness to own goods, some customers may reject servitized offerings due to a lack of long-term vision and a preference towards a more traditional way of thinking and acquiring. For instance, customers may decline full-risk maintenance contracts, as they try to minimize acquisition costs rather than maximize the long-term savings through additional services (ALGHISI; SACCANI, 2015).

Customers might also lack confidence in the firm's ability to deliver high-quality services, especially in the case of pioneering service extension companies (AHVENNIEMI;

MARTINSUO; NENONEN, 2014), or they may be concerned with losing control by signing a non-transferable ownership contract (BANERJI; ZHANG, 2017).

Given the mentioned challenges related to customers awareness and mindset, firms need to adopt adequate communication and training to increase their customers' cultural readiness. Indeed, communication is critical to transmit to customers the benefits of the service offer (ALGHISI; SACCANI, 2015).

2.3.7.3 Regulations (BUS03)

Regulatory frameworks can affect product functioning and serviceability (KREYE; VAN DONK, 2021). Moreover, institutional, and governmental structures govern copyright issues, tax and jurisdictional concerns that affect decision making regarding digital technology adoption (LE-DAIN et al., 2023). Therefore, collaborative engagement with government, regulatory bodies and industries are important (WEERABAHU et al., 2022) for the adoption of digital servitization.

This regulatory framework could be considered a barrier when it is not conducive to the digital transformation (LE-DAIN et al., 2023). Indeed, the lack of standards, regulations, and policies for digitalization and servitization influence digital servitization adoption (WEERABAHU et al., 2022).

Besides that, the diffusion of sustainable product-service offerings is heavily impacted by government policies. Indeed, some authors argue that governments should implement policy measures to stimulate directly and indirectly the diffusion of sustainable PSSs (VEZZOLI et al., 2015).

2.3.7.4 Economic changes (BUS04)

External factors are outside the organization and can influence the business landscape, favoring or hindering the adoption of new business models. They include changes in technology development, regulation, globalization (BANERJI; ZHANG, 2017), economy, and so on.

Economic changes can challenge the implementation of digital servitization. For instance, variations in labor availability and price may affect the selling of service provision. As explained by VEZZOLI et al., 2015, with an increasing cost of labor, it can be cheaper for customers to buy product-based offers, such as washing machines, instead of labor-intensive solutions like clothing care services.

2.3.7.5 Competitive environment (BUS05)

New sources of competition coming from actors within the company's supply chain have already been discussed under the topic of changing relationships and governance (SC01). Besides competition from players known by the firm, a more complex competitive environment involving different actors (HOU; NEELY, 2013) may arise.

For instance, as highlighted by MOSCH; SCHWEIKL; OBERMAIER, 2021, there is an increasing importance of software solutions in the deployment of digital servitization offerings. This results in the entrance of new and powerful suppliers from the information technology sector, which possess the critical software know-how. In that way, the presence of new entrants may harm the power position of traditional players.

2.3.7.6 Country specific (BUS06)

Several country specific factors negatively influence the provision of digital PSS, such as low personal safety index, higher costs for safety and security, foreign currency exchange procedures, customs restrictive procedures, unqualified technicians, low level of customer awareness (OWIDA et al., 2022), and unwillingness to sign contracts (PARIDA; REIM; SJODIN, 2016).

For instance, the exchange rates and customs difficulties can lead to difficulties in the supply of parts and tools. Moreover, unqualified technicians complicate repairing complex products and products installed in complex environments (OWIDA et al., 2022). To exemplify, PARIDA; REIM; SJODIN, 2016's work includes a case study in which a company Alpha considered offering PSS in Sudan risky, due to the lack of skilled service technicians, as well as other operational challenges.

Moreover, the diffusion of servitized offerings in the consumer market is dependent on the country's culture. For instance, authors researched by VEZZOLI et al., 2015 demonstrated that sustainable PSS offerings have been more readily accepted in communal societies like Scandinavia, the Netherlands and Switzerland in comparison to other countries.

2.3.8 Environmental challenges (ENV)

A PSS can be thoughtfully designed, developed, and delivered to be eco-efficient. However, it may be difficult to balance the overall performance with social/ecological issues (PACHECO et al., 2019), making it hard to achieve the sustainable goals. Some of the issues

are related to unwanted side effects, known as rebound effects, problems in quantifying the environmental benefits generated, and conflict of interests between actors in the supply chain.

Even well-designed sustainable PSS (S.PSS) solutions could generate unwanted side effects, due to unforeseen circumstances. One example is the impact of PSS on consumer behavior, where leasing rather than owning products, could lead to careless, less ecological, behaviors from customers (VEZZOLI et al., 2015). Thus, environmental performance of PSS can, in some cases, be worse if compared to traditional products offer, resulting only in economic benefits (PACHECO et al., 2019).

Moreover, there may be difficulties in quantifying the economic and environmental benefits from sustainable PSS, which is crucial for marketing the offer to stakeholders. Indeed, without including environmental and social costs in their market prices, it can become hard for sustainable PSS solutions to compete with industrially produced products (VEZZOLI et al., 2015).

Finally, in relation to the value chain, another barrier is represented by the potential conflict of interests between firms aiming to reduce volumes of material products sold and interests of retailers to increase them (VEZZOLI et al., 2015).

3 METODOLOGY

This chapter aims to explain the methodology, describing each phase of the study and the methods adopted for data collection and analysis.

3.1 Research phases

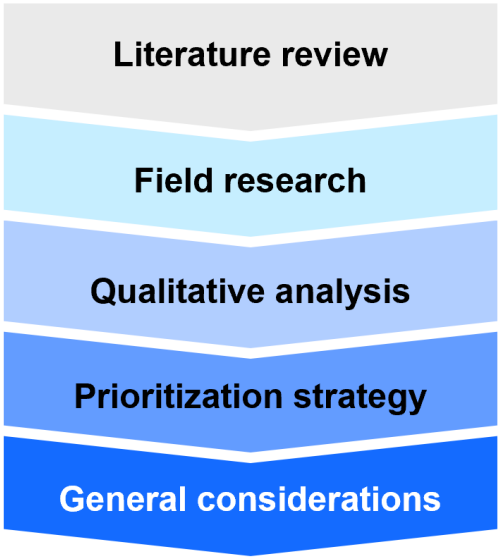
The research's goal is to identify, categorize and prioritize the main obstacles faced by companies adopting digital servitization as their business model, as well as identify the presence and role of different actors involved in the provision of digital-servitized offerings. This study is based on literature review and semi-structured interviews conducted with companies in Brazil and Italy.

As introduced in the first chapter, the objectives aimed by this research are to:

- 1: Identify, summarize and categorize the main barriers encountered by organizations when implementing digital servitization, through literature review.
- 2: Identify and categorize barriers for organizations implementing digital servitization, and identify the actors involved in the DPSS offerings, through semi-structured interviews.
- 3: For each company interviewed, classify barriers in terms of the difficulty to overcome (financial and time constraints) and the benefits (economic and non-economic), using a two-axis prioritization graph.
- 4: Analyze and compare the results from interviews using cross-case analysis and the literature, to validate and generalize the research's findings.

To accomplish the objectives, the research is structured in five main steps as shown in Figure 2: the literature review, field research, qualitative analysis, prioritization strategy and general considerations.

Figure 2 – Methodology structure



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The literature review allows the identification, understanding and categorization of the main barriers to digital servitization. The field research goes further, making it possible to deep dive into practitioners' perception of barriers and their importance, as well as identify the actors involved in the DPSS provision. The prioritization strategy makes it possible to visualize the main obstacles each company has and in which barriers they should focus their limited time and financial resources. The qualitative analysis allows the understanding of the data gathered in the previous steps and the comparison between companies. Finally, general considerations are drawn, including the comparison of the research's findings with the literature, in an attempt to contribute to the development of the topic under investigation. Such considerations are made throughout this thesis and are summarized in the conclusions chapter.

3.2 Literature review

To systematically review the literature, different queries were made through Scopus, a multidisciplinary database of research literature. Scopus was chosen as the search engine because it has filters that facilitate the identification and selection of articles and reviews and has a large base of quality titles covered: nearly 36,000 titles from over 11,000 international publishers, including over 34,000 peer-reviewed journals (KAMAL et al., 2020).

To identify articles related to barriers and challenges in the context of servitization, specific words were searched on the papers' titles, abstracts, and keywords. The most meaningful attempts are summarized in Table 2.

Table 2 - Literature search on Scopus

Date	Filters	Query Keywords	Number of results
11/12/2022	• Articles and reviews	servitization OR product service system AND supply chain	151
12/01/2023	• Articles and reviews • Subject area: engineering, business, management and accounting • Language: English	manufact* AND (servi*i*ation OR pss OR (service infusion) OR (integrated solution) OR (serviti*ed product) AND ((supply chain) OR (supply network)) AND (barriers OR challenges OR paradoxes))	58

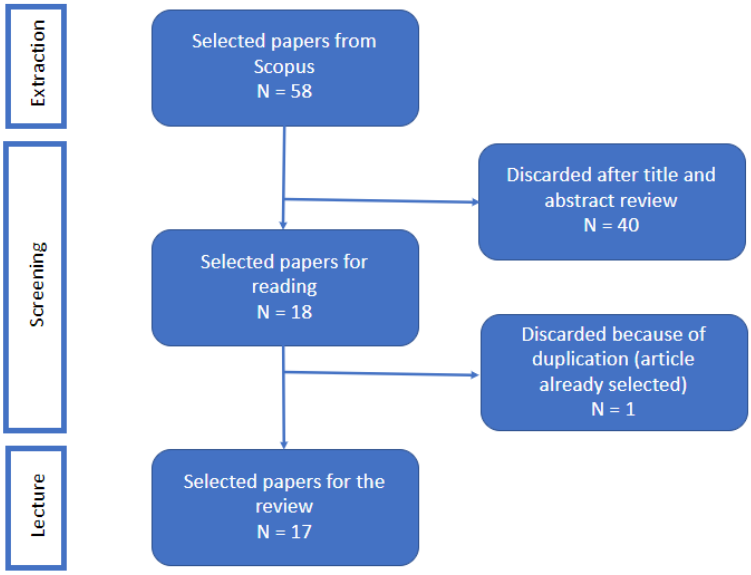
Source – Created by the author

The articles and reviews' abstracts were read and used to decide their relevance for the thesis, which was then confirmed after the supervisor's review and feedback. Such relevance was measured based on the mentioning of servitization and supply chain, while the mentioning of digital tools was considered a plus (and not restrictive) factor, to avoid over-limiting the results. From the first search attempt, three articles were recommended by the supervisor: BAINES; LIGHTFOOT; SMART, 2011, VENDRELL-HERRERO et al., 2017 and MOSCH; SCHWEIKL; OBERMAIER, 2021.

In the successive attempt, additional filters were included to refine the findings and facilitate the screening process. Thus, the articles and reviews were limited to the ones from the subject areas of engineering, business, management, and accounting, written in English. Additional keywords were used to restrict the context (focus on manufacturing) and include synonyms or related terms to avoid excluding papers because of differences in terminology.

Moreover, challenges, barriers, and paradoxes were included in the keywords and their mentioning was considered a relevance factor to select articles and reviews. From this second attempt, as shown in the scheme in Figure 3, seventeen additional papers were selected: WEERABAHU et al., 2022, KAMAL et al., 2020, BERTONI; LARSSON, 2011, BIGDELI et al., 2018, JOHNSON; MENA, 2008, KREYE; VAN DONK, 2021, PURVIS et al., 2021, MARIC; OPAZO-BASÁEZ, 2019 , ROBINSON et al., 2016, CHAKKOL et al., 2014, FINNE; HOLMSTROM, 2013, HOWARD; LEWIS, 2009, SPINLER; WERNING, 2020, OWIDA et al., 2022, VICTORINO et al., 2018, MONDAL et al., 2022, and REBELO, 2022.

Figure 3 - Papers' screening process



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Other papers were included in the literature review given the thesis' supervisors' recommendations and the necessity to deep dive in some topics.

Literature investigation, with the identification and categorization of the main barriers to digital servitization was made by using N-VIVO® platform. The software was used to store selected articles, highlight and divide the most significant fragments into main categories, and subcategories.

First, broad main categories were created in the software, based on the classification of servitization related benefits and challenges presented in KAMAL et al., 2020. The author used six dimensions, namely Strategy, Organization, Operational, Financial, Technological and Environmental (SOOFTE).

Then, the selected articles were read, and fragments were collected into the first six main categories. During this process, two other main categories were created, namely Business Context and Supply Chain, to collect barriers not comprised in the initial six categories. After that, the fragments of the literature were read again and divided into forty-four subcategories.

3.3 Data collection

The field research data was collected through semi-structured interviews with four companies implementing digital servitization.

3.3.1 Research protocol

To collect and structure data from interviewees' responses, the interviewer utilized a Microsoft Excel sheet. In a first moment, the sheet was filed with the barriers mentioned by the company's representative. Then, one barrier at a time, the interviewee was asked to classify the barrier as internal or external, naming actors involved in the issue. In a second moment, the interviewee classified the barrier's strength and impact. The dimension strength is composed by two subdimensions, namely time and financial resources (needed to overcome each barrier). The dimension impact is composed by two subdimensions, namely financial and non-financial benefits (obtained once the barrier is solved). To classify each barrier in every subdimension, the interviewee utilized a verbal scale composed by: "not relevant", "low importance", "medium importance", "high importance" and "very high importance". Such verbal scale was then converted into numbers from zero to four, being zero "not relevant", one "low importance", and so on.

However, for non-economic benefits valuation in company 4 (C4), the interviewee 4 (ID4_C4) preferred to describe how solving the barrier would be beneficial for the firm, without using the verbal scale proposed. In that case, the author interpreted the interviewee's comments and proposed numerical grades. The grades proposed considered four factors: generation of present gains, generation of future opportunities, improvement of internal procedures/operations, and enhancement of customers' perception. Each factor summed one point for the non-financial benefit described.

It is important to notice that the Excel sheet was filed in a collaborative manner by interviewer and interviewee, in a way that the interviewee could visualize all his/her previous answers for other barriers. That allowed the comparison of importance between barriers, guarantying better data. In some cases, the interviewee asked to add intermediate numbers (e.g. 2,5; 0,5) to classify a barrier's relevance. Moreover, interviewees were encouraged to provide examples to justify their answers, allowing the interviewer to gather useful information in terms of scale, for instance.

The semi-structured interviews of around one hour were guided through an interview protocol designed to capture interviewees' perspectives on the matter and support the interviewer. As presented in Appendix A, the protocol has 6 parts: (1) self-introduction and presentation of main concepts and examples, (2) company's context and supply chain, (3) barriers, (4) mapping the company's ecosystem and formalizing barriers, (5) prioritization, and (6) finalization of the interview.

The first part of the protocol aims to explain to the interviewee the reasons and goals of the research, as well as main concepts and examples. Then, in the second part, company's context and supply chain are explored to comprehend the firm's relevance for the study and understand initial topics, such as the company's path towards digital servitization and its product-service offerings.

The third part explores the barriers faced by the firm. After the interviewee's description of main challenges, the discussion is further instigated, as the interviewer names barriers' main categories and sub-categories found in the literature, allowing the interviewee to complement his/her initial list.

After that, in the fourth part, the firm's ecosystem is investigated, as the interviewee and interviewer draw together a map containing the focal company, its customers, suppliers, complementarians and key partners, if any. Then, in the fifth part, the barriers' responsibilities/influence, strength, and impact are explored for each challenge faced by the company.

Responsibilities/influence are related to classifying a challenge as internal (solely dependent on the company's decisions and under its control), or external (dependent on the action of external actors). In the case of internal challenge, the departments involved are identified, while external actors are identified for external challenges. Considering barriers' strength, interviewees are questioned about the difficulty of overcoming each barrier in terms of managerial time and financial resources required. Then to determine impact, benefits associated with the elimination of each challenge are explored, including financial and non-financial benefits.

Finally, by the end of the interview, the interviewer asks the interviewee for additional comments and validation on the results obtained from the exercises conducted.

3.3.2 Companies interviewed

The selected companies were recommended by the thesis' supervisors, given their relevance for this study and pre-existent contact points. They sell bundles of digital product-services, among other offerings, in a B2B market, and provide a certain degree of customization, depending on their clients' projects. Moreover, they adopt product-oriented PSS as their business model (TUKKER 2004), as it is mainly geared towards sales of products, with the addition of extra services. A brief description of the companies is presented in Table 3.

Table 3 - Selected companies' descriptions

Company's ID	Company's segment	Country	Company's description
C1	Medical equipment	Brazil	C1 is the leader in medical technologies with more than 170 years of experience, and present in more than 70 countries. It is specialized in precision medicine, and digitalized healthcare, with innovative technologies and services in the areas of diagnostic and therapeutic imaging, laboratory diagnostics and molecular medicine, healthcare digitalization and Enterprise Services.
C2	Software and service solutions (mechatronic, electrical engineering and automation)	Brazil	Founded in 1984, it has over 1,200 employees in more than 50 countries. It has developed one of the world's leading design software solutions for machine, plant, and panel manufacturers. It provides software solutions and services in the areas of electrical engineering, automation, and mechatronics, optimizing processes in engineering companies worldwide.
C3	Pneumatic conveying systems	Brazil	With its headquarters in the United States, it is also present in Brazil, China, and United Kingdom. It has over 50 years of expertise in designing and manufacturing pneumatic conveying systems and equipment for handling dry bulk solids. It is a leading provider of custom solutions for the handling of bulk materials for processing businesses across various industries.
C4	Industrial machines and automation	Italy	Founded in 1982, with its headquarters in Italy, it is also present in France, Slovenia, and Brazil. It conceives, designs, and creates machines and modules for the automation of assembling processes, operated in main fields of industry, such as electro-mechanics, electronics, and white goods.

Source – Created by the author

The respondents have senior positions within their companies and have relevant experience in the topic of digital servitization. The interviews were conducted and recorded using Microsoft Teams, with the assistance of a semi-structured questionnaire, as displayed in Annex A, and Microsoft Excel spreadsheet. The questions were made and answered in the native language of the interviewees, to allow more complete and detailed answers. Table 4 summarizes interviewees' IDs, roles, countries and the duration of each interview.

Table 4 – Interviews' details

Interviewee ID	Interviewee's role	Country	Interview platform/ duration
ID1_C1	Sales manager	Brazil	Teams, 1 h
ID2_C2	CEO	Brazil	Teams, 1:20 h
ID3_C3	Automation and Information Coordinator	Brazil	Teams, 1:25 h
ID4_C4	Innovation manager	Italy	Teams, 1h

Source – Created by the author

3.4 Data analysis

3.4.1 Intra-case analysis

In the intra-case analysis, the cases are analyzed separately, considering the responses obtained in the semi-structured interviews, whose protocol is presented in Appendix A. For each company the analysis contains two main parts: 1) company's context and supply chain and 2) barriers.

In the first part, the company is briefly described, including its products and services, the reasoning/motivation behind the adoption of digital servitization, and the actors involved in the provision and/or development of the PSS solution. Simplified figures of part of the company's supply chain containing these actors are schematized, displaying flows of products/services, money, and information.

In the second part, the barriers' identified by the interviewee are summarized in a table, called here table A, whose first two columns contain the level 2 categorization and the code

proposed for barriers, as displayed in Table 1. The third column contains the barriers' classification as internal or external, as explained in the research protocol. The fourth column displays the internal departments and/or external agents involved. Finally, the number of actors (internal and/or external) are summed in the fifth column.

Table A is useful for gaining visibility over the companies' barriers and for identifying the ones which require internal transformation and those that depend on the coordination with external agents, including details on the internal departments and/or external actors (e.g. client's sector, such as IT) involved. Moreover, this table allows to understand which barriers involve the highest number of actors and which actors are more frequently mentioned.

Then a second table, named here table B, summarizes the barriers' strength and impact. The dimension "strength" is composed by two subdimensions, namely time and financial resources (needed to overcome each barrier). The dimension "benefits" is composed by two subdimensions, namely financial and non-financial benefits (obtained once the barrier is solved). To classify each barrier in every subdimension, the interviewees utilized a verbal scale which was converted into numbers from zero to four, as explained in the research protocol.

From the results summarized in table B, two graphs are made: 1) a graph in which financial resources (horizontal axes) are compared to expected financial benefits (vertical axes) for each barrier and 2) a graph in which financial resources (horizontal axes) are compared to overall benefits expected (vertical axes). To compute the grade for overall benefits, present in the second graph, the grades for financial and non-financial impact are summed. The graphs' scales consider the grades summarized in table B and the sum mentioned.

In both graphs the time required to overcome the barriers is also displayed. In some cases, it is represented by the size of the dots plotted: the larger the dot, the higher the amount of time needed to overcome the barrier. In other cases, the darker the shade behind the barrier's name, the higher the amount of time required to surmount it. The representation of time using shades was an alternative to the use of size of dots in situations in which many dots overlapped.

The graphs representation also contains dashed-line circles, around the barriers prioritized. Such prioritization considered the barriers which occupied the top-left quadrant of one or both graphs. That quadrant was considered the priority, as it contains barriers that require the lowest financial resources and have the highest expected benefits.

When no barriers clearly occupied the top-left quadrant, linear-trend lines were drawn, to observe the general tendency. The barriers positioned above (and to the left) the trend line were the ones selected as the priority. That is because with the same financial resources, they are expected to generate higher benefits than the average.

Additionally, the prioritization also considered the time to overcome barriers, represented in the graphs. Among the barriers prioritized, the ones requiring less time were considered more relevant in the short-term.

Finally, additional comments provided by the interviewees were displayed, to help understanding the magnitude of resources and impact considered. Moreover, interviewees also provided some considerations on how to solve the barriers.

3.4.2 Cross-case analysis

In the cross-case analysis, the results obtained in the intra-case analysis where compared, to identify similarities and differences among companies and create general considerations. The cross-case analysis is divided into two main sections: 1) context and supply chain and 2) barriers.

In the first section, supply chain similarities are highlighted. Moreover, the Brazilian market context, where C1, C2 and C3 are inserted, and where C4 has a branch, is discussed. In the second section, comparative tables are used to summarize the results obtained in the intra-case analysis. First, the barriers' occurrence is evidenced, allowing the identification of the most mentioned barriers and categories. Then, by confronting the strength and impact grades, it is possible to identify the most challenging and the most beneficial barriers (once solved), and the ones prioritized more often by different companies.

4 RESULTS

This chapter shows the qualitative analysis results. First, each interview was analyzed separately, and the barriers found were explored considering the companies' context. For each company, departments and actors involved in each barrier were identified, providing visibility in terms of responsible/affected parts. Besides involved parts, barriers' strength and impact factors were also identified to compose individual prioritization matrixes for each company.

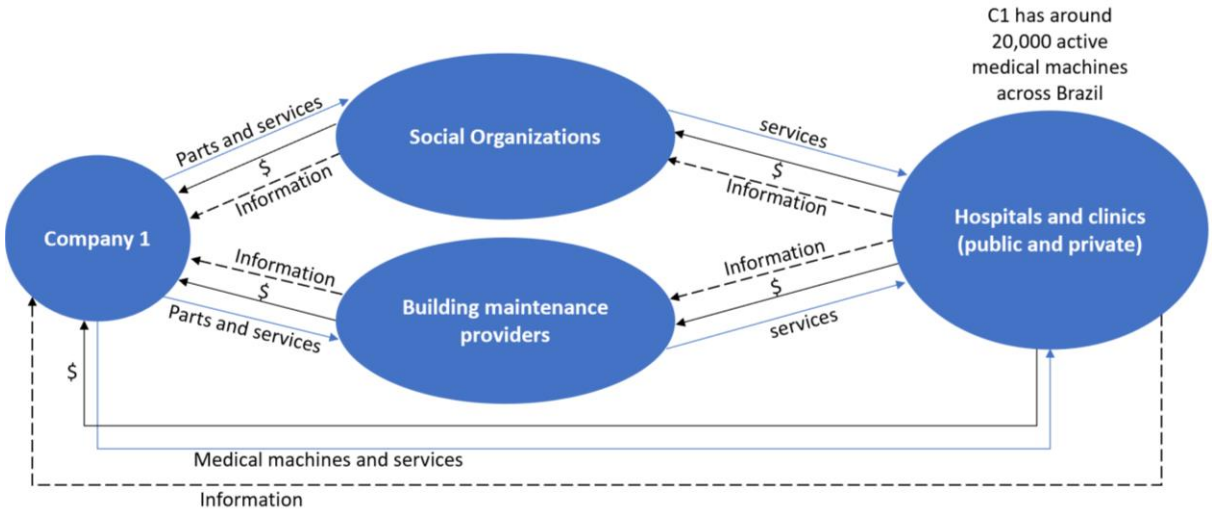
Second, a cross-case analysis was conducted, to explore commonalities and differences among companies. The analysis was built considering the interviewees' responses, summarized by Microsoft Excel sheets. Moreover, the interviews' transcriptions were useful in detailing barriers with examples.

4.1 Company 1 (C1) – Medical equipment

4.1.1 Company's context and supply chain

Company 1 (C1) sells equipment and services to hospitals and clinics in the health market, with around 20,000 active medical machines across Brazil. It also supplies parts and services to service providers and intermediaries, which then sell to hospitals and clinics. To exemplify, service providers include social organizations and building maintenance providers, which may lack expertise on medical equipment maintenance and need C1 to complement their package of services. A simplified scheme of a part of C1 supply chain is represented in Figure 4.

Figure 4 – Part of C1's supply chain



Source – Created by the author

The digital services sold by C1 to intermediaries, hospitals and clinics are entirely performed by C1, without technical partners. The company also builds the solutions in-house. According to the interviewee (ID1_C1), the choice for vertical integration is justified by the lack of qualified players/partners in the market, as C1 was the pioneer in offering advanced solutions in Brazil.

In the context of digital servitization, C1 seeks to digitize their services to increase speed and availability, offering a better solution to their clients. The digital services offered by the company involve remote access to its customers' medical machines and include remote support for repairs and diagnosis work (e.g. C1 experts can help the hospital/clinic carry out a diagnosis for a patient), and software that captures data from the customer's equipment to improve its performance and/or conduct diagnostics on faulty machines for maintenance and preventive maintenance.

The company adopts different commercialization strategies. Its customers can buy a package of digital and non-digital services together with the machine, or they can buy the equipment and then the services separately. Moreover, clients can buy services on an on-demand basis, depending on their needs, or sign periodic contracts (e.g., monthly payments).

Considering the company's market, Brazilian customers are aware of the need for basic maintenance. However, according to the ID1_C1, selling additional services (e.g., preventive maintenance) can be challenging, as the Brazilian market does not have a high financial freedom, not allowing investments without certainty of return. Such certainty is hard to obtain, as there are significant return variations depending on the client's demand (e.g., the number of clinical diagnoses they conduct on a month), the technical capacity of their team, and the maturity and size of their business.

The barriers mentioned in the interview are explored in detail in the next section.

4.1.2 Barriers

ID1_C1 is the sales manager at the services division in the company C1. He identified ten barriers for digital servitization within the organization, which are summarized in the Table 5, which follows the model of "table A", explained in the intra-case analysis section in the methodology chapter.

Table 5 – C1: Barriers' identification and actors involved

Barrier	Code	Internal or external	Departments or actors involved	Number of departments/ actors involved
Servitized offer cannibalizing physical products	STR09	Internal	Marketing, Business, and PLM	3
Support and service delivery	OPE01	Internal	Marketing and Technical team	2
Capability to communicate and sell the offer	OPE03	Internal	Marketing and Sales	2
Measurement of performance and savings	OPE04	Internal and external	Sales, Technical team, and Client	3
Systems for data collection and management	TEC03	External	Third-party TI suppliers	1
Risks related to data and technology	TEC04	Internal and external	Technical team and Client	2
Customer awareness and mindset	BUS02	Internal and external	Sales and Client's technical team	2
Regulations	BUS03	External	Government	1
Economic changes	BUS04	External	Client	1
Country specific	BUS06	External	Latin America, Africa, remote regions	-

Source – Created by the author

From the barriers identified, four were classified as external, three as internal, and three as both internal and external. The company's departments related to the barriers are Marketing, Business, PLM (Product Lifecycle Management), Technical team, and Sales. Marketing, Technical team and Sales were mentioned three times each, Business and PLM were mentioned once. The external actors mentioned were Clients' technical team, Third-party TI suppliers, and the Government, each one mentioned once.

The barriers with the highest number of actors involved are servitized offering cannibalizing physical products and measurement of performance and savings. The measurement of performance and savings requires an additional coordination effort, as internal and external actors need to collaborate in the matter.

Finally, when talking about country-specific barriers, some countries were mentioned as presenting cultural and technological infrastructure issues: Latin American countries, African countries, and countries in remote areas.

Besides the departments/actors involved, ID1_C1's perception on barriers' strength and impact was registered and the results are shown in Table 6. Table 6 follows the model of "table B", explained in the intra-case analysis section in the methodology chapter.

Table 6 – C1: Barriers' strength and impact

"0" – not relevant; "4 – very high importance"

Barrier	Barriers		Benefits	
Code	Time	Financial resources	Financial benefits	Non-financial benefits
STR09	1	0	2.5	3
OPE01	2	2	3	3
OPE04	2	1	3	2.5
OPE03	1	1	3	3
TEC03	4	1.5	2	3
TEC04	1	1	3.5	3
BUS06	4	2.5	2.5	3
BUS03	3	2	0	3
BUS02	2	1	2	2
BUS04	1	1	0.5	2

Source – Created by the author

The barriers which require the largest amount of time to overcome are TEC03 (systems for data collection and management) and BUS06 (country specific). This occurs because these barriers are related to lack of technological infrastructure, which may take a long time to be established. Moreover, deep-rooted cultural aspects, included in country-specific barriers, contribute to the late adoption of digital solutions.

Indeed, the issue related to TEC03 comes from the fact that some clients do not have systems for data collection and management, or the technological infrastructure needed. To solve this challenge, a long time is required, as mentioned by ID1_C1: "*A customer in a remote region may have an intermittent electricity supply and no internet stability. In this case, the resolution time is very long, over one year*". Moreover, C1's potential client may have to spend significant financial resources contracting IT suppliers to develop and install a system that allows the collection and management of data, which can hinder the sale of services by C1.

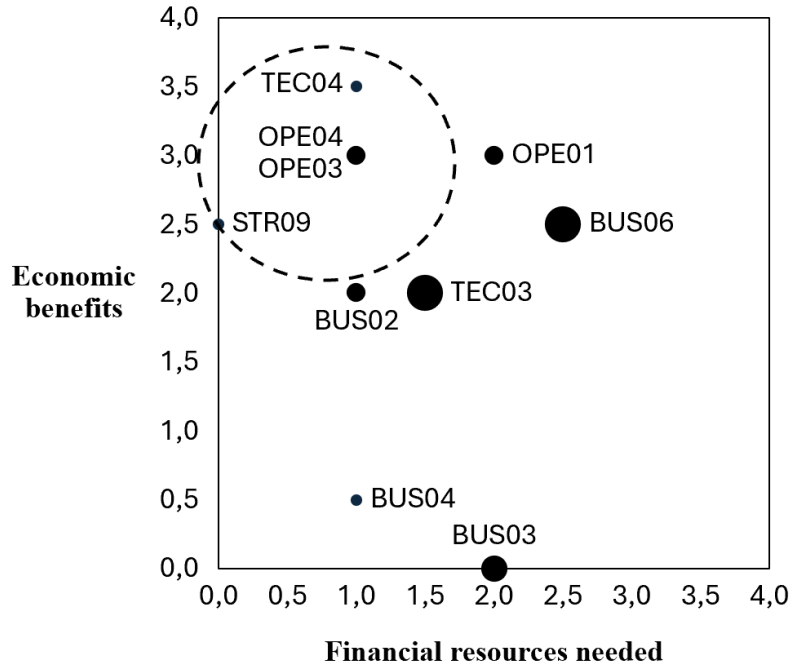
Additionally, in ID1_C1's perception on country specific barriers (BUS06), some countries present obstacles in terms of culture, making potential clients less open to digital solutions, and infrastructure, with lack of proper internet connection and availability of energy. In his vision: "*the time needed to overcome this obstacle is significant, spanning over several years*". He referred to countries in development as having higher country specific barriers in comparison to developed ones.

Moreover, in comparison to other barriers, country specific ones require the largest financial investment from C1. That is explained by the potential investment C1 could have to make to enable the provision of services: "*the financial investment on C1 side is moderate to high, as we could have to provide infrastructure to the client to enable service provision*".

The barrier with the largest financial benefit once solved is TEC04 (risks related to data and technology) and is related to risk mitigation. As explained by ID1_C1: "*The financial investment is not high, and includes a safety net, firewall installation and so on. The expected economic benefits come from risk mitigation*". To explain the magnitude of the loss the company avoids by investing in data and technology security, ID1_C1 provided an example in which another player in the market suffered a hacker attack: "*It had its patients' data leaked. This generated a huge cost, as the operation was halted*". Moreover, other benefits in mitigating these risks include preserving the company's image.

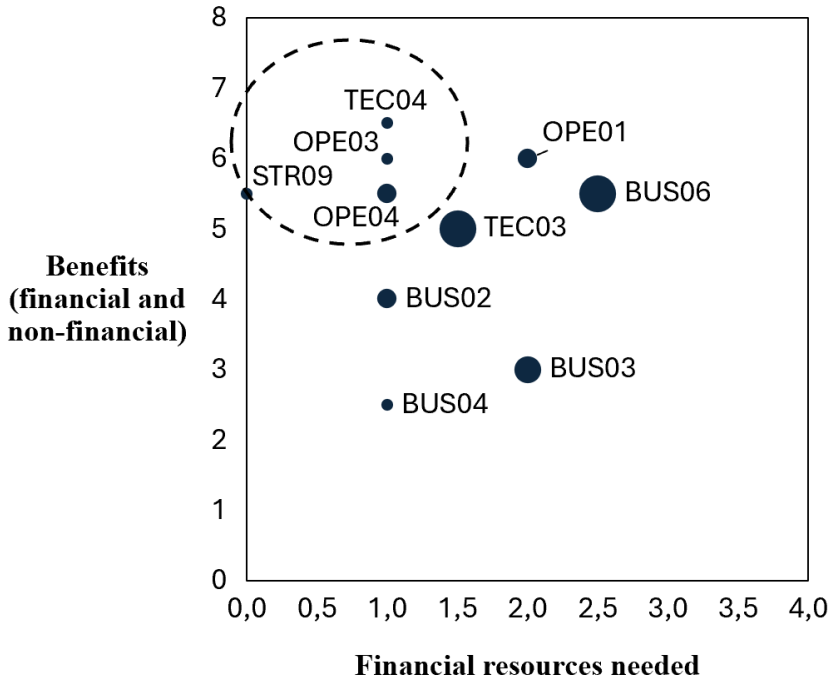
From the results summarized in Table 6, Graphs 1 and 2 were made. In Graph 1 financial resources are compared to expected financial benefits. In Graph 2 financial resources are compared to overall benefits expected (financial and non-financial). In Graphs 1 and 2 the size of the dots refers to the time required to overcome the barriers. The larger the dot, the higher the amount of time needed.

Graph 1 – C1: Prioritization 1



Source – Created by the author

Graph 2 – C1: Prioritization 2



Source – Created by the author

By comparing Graphs 1 and 2, it can be observed how the barriers' impact change when non-financial benefits are considered. The identification of such benefits is an important exercise for companies, to avoid overlooking initiatives that do not generate important financial

returns but contribute in different ways to the firm's goal. An example of this is the barrier BUS03, as its importance is exclusively due to expected non-financial impact.

Moreover, from Graphs 1 and 2 it is possible to observe that in general, for C1, barriers which require more time also need higher financial resources (i.e. BUS06, TEC03, and BUS03), being the hardest challenges for the company. These barriers should not be ignored, especially the ones with high expected benefits, such as BUS06 and TEC03. However, there are some barriers which are easier to solve in a shorter time, and provide significant benefits (i.e. TEC04, OPE03, OPE04, and STR09). These barriers should be prioritized by the company, considering a short-time horizon.

Indeed, to address risks related to data and technology (TEC04) C1 takes "*a few weeks and the financial investment is not high*", as explained by ID1_C1. However, it is important to highlight that efforts should be done both internally, by the company's technical team, and externally, by the client. Once the problem is solved, the financial and non-financial returns expected are high. Nonetheless, as mentioned by ID1_C1, the financial benefits are related to risk mitigation rather than increment in revenues.

Issues related to the company's capability to communicate and sell the offer (OPEO3) involve the Marketing and Sales teams, and are considered easy to be solved, both in time and financially. The financial and non-financial results from an improvement in the mentioned capabilities are expected to be high, as they increase customer awareness, as explained by ID1_C1: "*The time and financial resources required are low and related to the Sales' team training, to improve their capability to communicate and sell the offering. The economic benefits are relevant, as a trained Sales' team can close more deals. Moreover, other benefits involve better serving the clients*".

To measure the performance and savings of the offering (OPE04), the company needs little time and money, as the procedure is well-known by the company. Moreover, it is considered an essential practice, to convince customers on buying C1's solution. In ID1_C1's words: "*We must collect and analyze potential clients' data, create, and send a report and answer questions. It takes about two to three months. The financial investments are low and include the development of the study over the clients' potential benefits. The expected economic impact is just as great as improving the capacity of the Sales' team. That is because the measurement of the benefits is essential for convincing clients.*"

Finally, to avoid the cannibalization of physical products by the servitized offering, C1 invests just a small amount of time and no additional financial resources. This occurs as the

procedure to analyze the impact of a new offering in the company's portfolio is a well stablished practice by C1. Indeed, ID1_C1 mentions that: "*When launching a new product, the company sets meetings to analyze and discuss about its impact on the current portfolio, in a way to avoid cannibalization. To do so, the company takes a brief period, about weeks. No additional financial resources are needed, as these meetings are part of the company's protocol*". As ID1_C1 explains, the economic benefit is medium, and other benefits are related to the creation of a portfolio that allows greater customer loyalty and satisfaction.

4.2 Company 2 (C2) - Software and service solutions

4.2.1 Company's context and supply chain

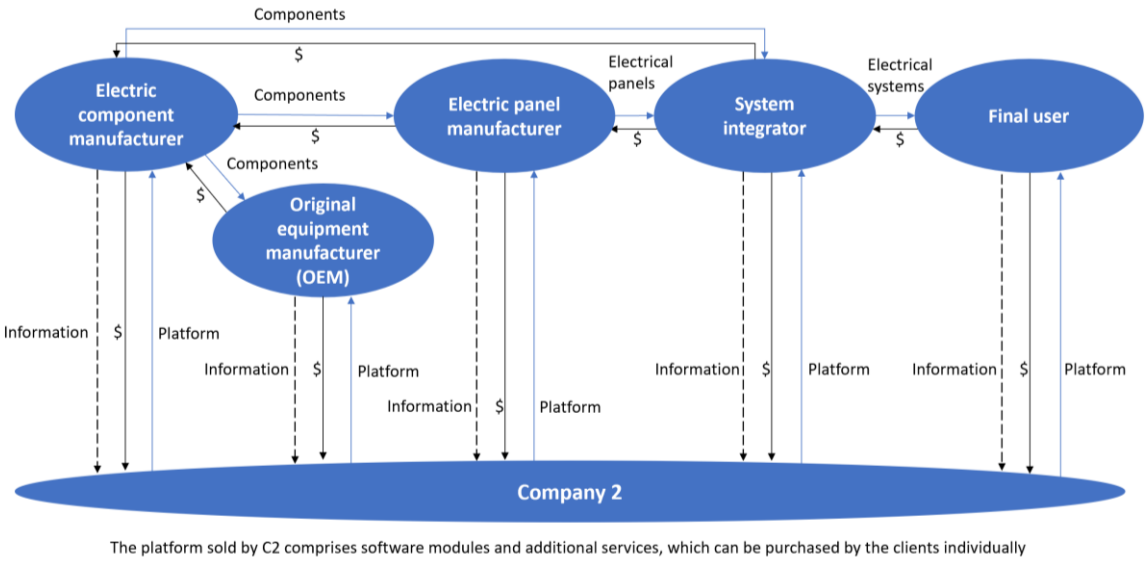
C2 is a market leader in selling engineering software primarily focused on electrical and automation design solutions. Their software aids engineers and designers in creating, documenting, and managing electrical, fluid power, and instrumentation designs. Its software suite, comprised in C2's platform, streamlines the engineering design process, enhances collaboration among team members, and improves overall project efficiency.

Some examples of C2 software offerings include: (1) a software used for electrical design, with capabilities for schematic creation, panel layout, and documentation generation; (2) a tool specialized for 3D enclosure layout and cabinet design, facilitating the planning and assembly of control cabinets and switchgear; (3) a software that assists in the creation of hydraulic and pneumatic schematics, as well as the generation of associated documentation; (4) a solution that aids in the initial stages of design by providing tools for conceptual planning, feasibility studies, and early-stage project visualization. The clients can buy the entire platform, composed by all the items mentioned, or individual modules.

By selling solutions to many players in the electrical engineering segment, C2 has access to a big volume of data from component manufacturers, original equipment manufacturers (OEMs), electric panel manufacturers, system integrators and end users. Such data is converted into useful information, and in additional services, sold by C2 in parallel to its software offerings, enhancing its clients' projects. These additional services are included in C2's platform.

To illustrate C2 interactions with its clients, a simplified scheme of its supply chain is represented in Figure 5.

Figure 5 – Part of C2's supply chain



Source – Created by the author

The selling of digital services by C2 was influenced by an improvement in technology and the accumulation of information, throughout the interaction with different agents in the production chain. This highlights the importance of information access to create and sell new services, in the context of digital servitization.

To exemplify some of the additional services, C2 included into its software offering the access to a huge database of electrical components, with detailed technical and commercial features. Besides that, clients can connect their electrical panels to their digital projects, via IoT. In this way, they can gather data from their equipment in operation and, thus, information to take predictive action.

4.2.2 Barriers

ID2_C2 is the CEO of the company. He identified fourteen barriers for digital servitization within the organization, which are summarized in Table 7. Table 7 follows the model of "table A", explained in the intra-case analysis section in the methodology chapter.

Notice that the barrier coded as FIN01 appears twice (FIN01A and FIN01B). That happens because ID2_C2 considered important to evaluate the risks and impact from profitability issues separately from pricing issues.

Table 7 – C2: Barriers' identification and actors involved

Barrier	Code	Internal or external	Departments or actors involved	Number of departments/ actors involved
Development and/or buy new competencies	STR02	Internal	Technical team and HR	2
Changing/complex business models and methods	STR06	Internal and external	Sales and High management	2
Servitized offer cannibalizing (physical, standard) products	STR09	Internal	High management	1
Capability to communicate and sell the offer	OPE03	Internal	Sales	1
Training and hiring	ORG04	Internal	All departments	many
Profitability	FIN01A	Internal	Sales and Finance	2
Pricing	FIN01B	Internal	Sales and Finance	2
Cash flows	FIN02	Internal	Finance	1
Lack of technology, skills and understanding	TEC01	External	Client's Engineering team, Software team, and Systems' designer	3
Risks related to data and technology	TEC04	External	Client's High management, TI, and Technical team	3
Technology strategy	TEC06	External	Client	1
Partners competencies, maturity, training, and awareness	SC04	External	Component manufacturer, Original equipment manufacturer (OEM), Panel manufacturer, and end user	4

Customer awareness and mindset	BUS02	External	Client's Management	1
Country specific	BUS06	External	Brazil	-

Source – Created by the author

From the barriers identified, six were classified as external, seven as internal and one as internal and external. The company's departments related to the internal barriers are the Technical team, HR, Sales, Finance, and the high management. Sales was mentioned four times, Finance three times, high management twice, and Technical team and HR were mentioned once.

The external actors mentioned were the client's Engineering team, Software team, Systems' designer, TI, Technical team, the client's management, and high management. Each external actor was mentioned only once, except from the client's high management team, which was mentioned twice. Different actors composing the value chain were mentioned as related to barriers: component manufacturers, OEMs, and panel manufacturers.

In addition, ID2_C2 mentioned that all company's departments are involved in or impacted by training and hiring, sustaining the idea that the implementation of digital servitization implies a profound change in the entire organization. Indeed, this barrier is the one with more actors involved, meaning that it requires special attention in coordinating.

Besides that, on country-specific barriers, ID2_C2 mentioned the existence of challenges in countries with poor adoption of advanced technologies. He exemplified this idea with obstacles faced by C2 in Brazil, due to a lack of IT infrastructure in some potential clients. For instance, in some cases, the selling of the offering was not made, because the potential client had a very old version of Windows, in which C2's software was not programmed to work: "*here, there are people working with Windows 10, so it (the software) doesn't work*". Moreover, ID2_C2 considers the country's poverty in some areas to be a major obstacle to selling innovative software.

Other than the results presented on the first table of this sub-section, ID2_C2's perception on barriers' strength and impact was registered and the results are shown in Table 8. Table 8 follows the model of "table B", explained in the intra-case analysis section in the methodology chapter.

Table 8 – C2: Barriers' strength and impact

"0" – not relevant; "4 – very high importance"

Barrier	Strength	Impact

Code	Time	Financial resources	Financial benefits	Non-financial benefits
STR09	4	3	4	4
STR06	3	4	4	4
STR02	2	1	2	0
ORG04	3	2	4	4
OPE03	2	2	4	4
FIN02	4	4	4	1
FIN01A	4	2	4	4
FIN01B	2	2	4	4
TEC01	4	1	3	1
TEC06	4	0	2	3
TEC04	2	1	1	0
SC04	3,5	1	2	5
BUS06	4	4	4	4
BUS02	4	0	2	3

Source – Created by the author

The barriers which require the largest amount of time to be solved are STR09 (servitized offer cannibalizing physical/standard products), FIN01A (profitability), FIN02 (cash flows), TEC01 (lack of technology, skills and understanding), TEC06 (Technology strategy), BUS02 (customer awareness and mindset), and BUS06 (country specific).

Indeed, the introduction of new products which cannibalize pre-existing offerings (STR09) requires a long time from C2 to prepare. According ID2_C2: "*It takes about one year to prepare the implementation of the new model and avoid losses*.". He also mentions a high amount of time to overcome profitability issues (FIN01A): "*Four years would be required to obtain the same level of profitability we had before the change in the business model.*"; and cash flow issues (FIN02): "*The new subscription model is very demanding in terms of cash flow management. The time and money spent in constantly managing the cash flows are very high.*".

Similarly, to surmount the lack of technology, skills and understanding challenges (TEC01), technology strategy issues (TEC06), lack of customer awareness and appropriate mindset (BUS02), and country specific issues (BUS06), C2 needs to employ a long time. As mentioned by ID2_C2: "*this issue (TEC01) is related to cultural factors of our clients and their*

employees (...) we try to overcome this obstacle through a marketing effort, which takes a long time.". The same happens to technology strategy issues (TEC06), since "*clients lack appropriate technology strategies, to understand the value added and trust the servitized offering*". Likewise, C2 needs a long time to gain customers' trust and overcome BUS02 and to overcome challenges related to poor adoption of advanced technologies and surmount BUS06.

The barriers which need the highest amount of financial resources are STR06 (changing/complex business models and methods), FIN02 (cash flows), and BUS06 (country specific). Indeed, to adopt the new business model, the company had to invest a significant amount in reconfiguring internal areas, and to adapt. As mentioned by the interview: "*Once the decision to modify the business model is made by the top management, the commercial area needs to be completely reconfigured, from the head to the salespeople. The financial cost perceived with the adoption of the new model is very high.*". Moreover, as discussed, the money spent by C2 in constantly managing the cash flows are very high. Similarly, high investments need to be made to surmount country specific barriers (BUS06), both in marketing efforts and to build the necessary technological infrastructure.

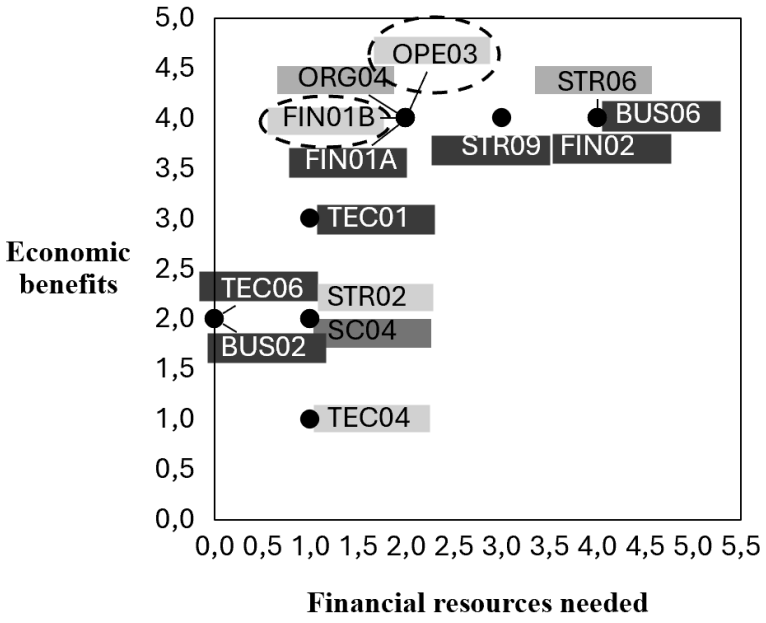
The economic benefits are expected to be high for several barriers. This can be due to the positive expectations of ID2_C2 in implementing the new business model, as the CEO of the company. Indeed, he expects that the returns will be significant, once the number of customers in the subscription model is large enough. Moreover, he believes that improvement in the commercial team's capacities generate very high economic benefits, being essential for generating revenue, creating new relationships with customers, and driving new deals. Finally, he believes that by solving country specific barriers, the company can create new business opportunities, with significant return.

The barrier with the highest non-financial benefit once solved is SC04 (partners competencies, maturity, training, and awareness). In ID2_C2's words: "*other benefits are extremely high, because if the actors in the value chain understand and accept C2's model, it triggers a new way of working efficiency in the ecosystem. It could increase supply chain visibility, in terms of data, connecting all the links in the value chain.*".

From the results shown in Table 8, it was possible to draw the Graphs 3 and 4. In Graph 3 financial resources are compared to financial benefits. In Graph 4 financial resources are compared to financial and non-financial benefits. In Graphs 3 and 4 the shade of the barriers'

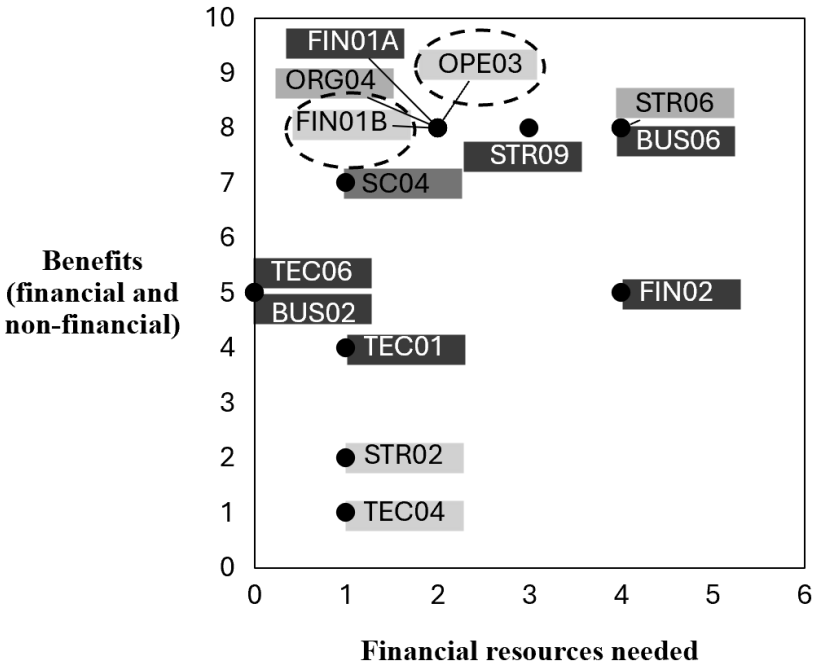
codes refers to the time required to overcome them. The darker the shade, the higher the amount of time needed. Differently from the graphs displayed in C1, many points are overlapping, thus the differentiation using dot dimensions is not efficient, as one dot hides behind the other.

Graph 3 – C2: Prioritization 1



Source – Created by the author

Graph 4 – C2: Prioritization 2



Source – Created by the author

From Graphs 3 and 4 it is possible to observe that BUS06 (country specific) and FIN02 (cash flows) are the hardest challenges for the company. They take a long time and significant financial resources to be solved. However, even if they are not the priority for the company in the short time, they should not be overlooked. That is the case especially for BUS06, as it has a high potential for benefits.

By comparing the results from both graphs, the priority for C2 is to focus on addressing issues related to pricing (FIN01B), and capability to communicate and sell the offer (OPE03) in a first moment. That is because these issues are cheaper to overcome, require low amount of time and have more positive impact in comparison to other barriers. Moreover, they involve few internal departments, as FIN01B involves only Sales and OPE03 involves Sales and Finance. Thus, there is lower complexity in managing efforts form distinct departments.

According to ID2_C2, to overcome pricing issues (FIN01B), C2 must understand the average prices practiced in the market. To do so, it would spend moderate financial and time resources. The benefits expected are very high. Moreover, to increase the capability to communicate and sell the offer (OPE03), ID2_C2 mentioned that it is necessary to train the commercial team. The financial and time expenditures are moderate. The expected benefits are very high, as the activity of the commercial team is perceived as essential for generating revenue, creating relationship with customers, and driving new offerings.

4.3 Company 3 (C3) – Pneumatic conveying systems

4.3.1 Company's context and supply chain

C3 is an American multinational company with its headquarters in Minnesota. The subsidiary in Brazil has twenty-five years and around two hundred and ten employees. The company supplies pneumatic conveying equipment for industrial clients, including hermetic closed pipes and mixers. It also sells individual equipment, such as mixers, transporters, electrical control systems, among others; process systems, including mixing, blending, feeding, weighing, batching and storage solutions; monitors the equipment assembly and automation, and provides advanced services. C3 has large clients, including PepsiCo, Bridgestone, Michelin, and Unilever.

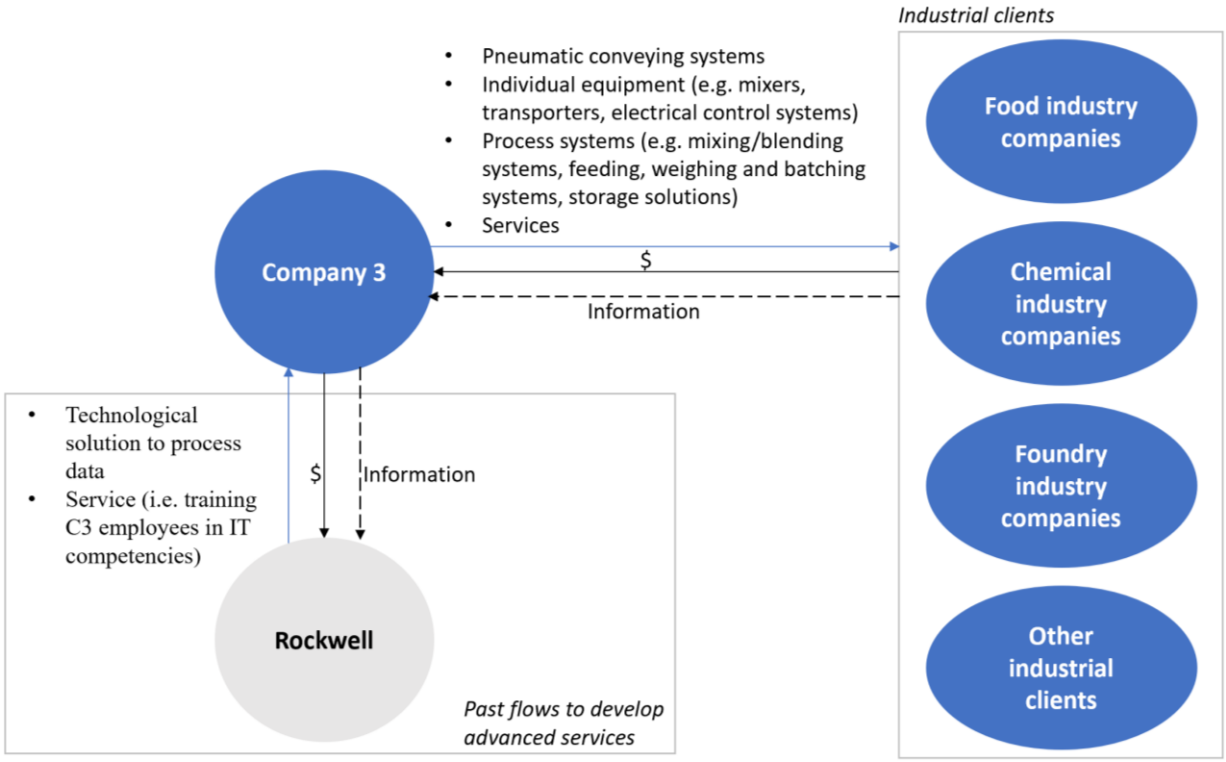
Before offering advanced services, the company already supplied equipment with sensors to its clients. However, in its transition towards digital servitization, C3 needed to develop IT

competencies to process the data and turn it into information, reports, and graphs, generating value for its clients and new revenue sources for the company.

Therefore, C3 invested in training its employees and partnered with Rockwell, a world leader in industrial automation, to develop a technological solution, allowing managers to control real-time events in their equipment and production processes remotely.

Despite the partnership in developing the technological solution, C3 offer is currently delivered without external partners, a strategic choice to preserve its autonomy in service provision. A simplified scheme of C3 supply chain is Figure 6.

Figure 6 – Part of C3's supply chain



Source – Created by the author

To better understand the advanced services provided by C3, it is valid to mention that its equipment's IIOT sensors are connected to a Human-Machine Interface (HMI) and a Programable Logic Controller (PLC).

The HMI is the interface between the processing machine and the operator: through a software, the operator panel displays operational information in near real time (e.g., engine and valve status), allowing control and optimization. Moreover, through the HMI, the line operator or manager can access historical and trend data relating to machine efficiency or product quality.

The PLC works as a process control system: it acts on the sensor readings, issuing commands to the actuators. To exemplify, based on its readings, the PLC can record data in real time (e.g., operating temperature and machine productivity) and start and stop a process or generate malfunction alarms.

Thus, through the TED-D solution, C3 clients have access to remote monitoring, including information on production volumes, factory down times, maintenance information on the engines, and so on. This information is valuable for the production management, as it increases control and predictability, allowing, for instance, predictive maintenance.

When buying a pneumatic conveying system, C3 clients receive the TED-D solution for a year without additional costs. After the first year, a monthly fee is charged from the clients who wish to continue with the service, representing a recurring revenue for the company.

Considering the customer awareness towards advanced solutions, ID3_C3 stated that many customers are still not actively looking for Industry 4.0 solutions. Moreover, she mentioned resistance from a large company's maintenance team, which is not interested in having machine failures reported. However, despite the low awareness and some resistance, when clients understand the benefits provided by TED-D, they welcome the solution.

4.3.2 Barriers

ID3_C3 currently holds the position of Automation and Information Engineering coordinator in the company C3. She identified sixteen barriers for digital servitization within the organization, which are summarized in Table 9. Table 9 follows the model of "table A", explained in the intra-case analysis section in the methodology chapter.

Table 9 – C3: Barriers' identification and actors involved

Barrier	Code	Internal or external	Departments or actors involved	Number of departments/ actors involved
Development and/or buy new competencies	STR02	Internal	IT, AT, Technical support	3
Lack of vision and understanding	STR07	Internal	Technical support and After sales	2

Capability to communicate and sell the offer	OPE03	Internal	Sales	1
Culture shift, resistance/fear, and awareness	ORG01	Internal	Technical support, Sales and After sales	3
Internal conflicts and silos	ORG03	Internal	Technical support, Sales and After sales	3
Training and hiring	ORG04	Internal	IT, AT, and After sales	3
Resource limitation and high investment	FIN03	Internal	IT and AT	2
Lack of technology, skills and understanding	TEC01	Internal	IT and AT	2
Systems for collaboration	TEC02	External	Client's IT	1
Systems for data collection and management	TEC03	Internal	IT and AT	2
Risks related to data and technology	TEC04	External	Client's IT	1
Technology high complexity	TEC05	Internal	IT, AT, Technical support and After sales	4
Technology strategy	TEC06	Internal	Technical support, After sales, Spare parts	3
Collaboration and information sharing	SC02	External	Client's IT and client's operations team	2
Recognition of market demand	BUS01	Internal	AT and After sales	2
Customer awareness and mindset	BUS02	External	Client's project team	1

Source – Created by the author

From the barriers identified, four were classified as external and twelve as internal. The company's departments related to the barriers are IT (information technology), AT (automation technology), Technical support, After Sales, Sales, and Spare parts. AT and After sales were

mentioned seven times each, Technical support and IT were mentioned six times each, Sales three times, and Spare parts once. The external actors mentioned were clients' IT, Operations and Project teams. Clients' IT was mentioned three times, while clients' Operations and Project teams were mentioned once.

Additionally, the barrier with the highest number of actors involved is technology high complexity (TEC05), indicating that a significant coordination effort among technical (IT, AT, and Technical support) and non-technical (After sales) areas may be required.

Besides the departments/actors involved, ID3_C3's perception on barriers' strength and impact was registered and the results are shown in Table 11. Table 11 follows the model of "table B", explained in the intra-case analysis section in the methodology chapter.

When analyzing the non-economic benefits, ID3_C3 preferred to describe how solving the barrier would be beneficial for the firm, without using the verbal scale proposed. In that case, numerical grades were proposed by the author, which is shown in Table 10.

Table 10 details how non-financial benefits comments provided by ID3_C3 were converted into numerical grades by the author. It considered four factors: generation of present gains, generation of future opportunities, internal procedures/operations improvement, and enhancement of customers' perception. Each factor summed one point for the non-financial benefit described, as mentioned in the intra-case analysis section in the methodology chapter.

Table 10 – C3: Numerical grades for non-financial benefits

Non-financial benefits comments	Present gains	Future opportunities	Better internal procedures/ operations	Better customers' perception	Proposed grades
New business opportunities, delivery optimization, increase in product's value.	1	1	1	1	4
Benefits clearer to the customer, improvement in communication.	1	0	0	1	2
Greater understanding and improvement in equipment.	1	0	1	0	2

Innovative technology through continuous investment.	0	1	1	0	2
Company distinguishes itself as a pioneer in digitalization, in a way that customers come spontaneously to discover the company's solutions.	1	0	0	1	2
New business opportunities.	1	1	0	1	3
Better data latency, fewer slowdowns, and more flexibility, thanks to good data management. It delights the customer.	1	0	1	1	3
Customer's perception of safety, which facilitates data collection and dashboard construction.	1	0	1	1	3
Credible digital transformation.	1	0	0	1	2
Active team, which informs the possibility of failures, instead of being passive.	1	0	0	1	2
Customer delight.	1	0	0	1	2
Customer's value perception and improvement in customer's production.	1	0	0	1	2

Source – Created by the author

Table 11 – C3: Barriers' strength and impact

"0" – not relevant; "4 – very high importance"

Barrier	Strength	Impact

Code	Time	Financial resources	Financial benefits	Non-financial benefits	Proposed grades for non-financial benefits
STR02	3	1	3	New business opportunities, delivery optimization, increase in product's value.	4
STR07	2	2	3	New business opportunities, delivery optimization, increase in product's value.	4
OPE03	2	2	3	Benefits clearer to the customer, improvement in communication.	2
ORG01	3	3	4	Greater understanding and improvement in equipment.	2
ORG03	3	3	4	Greater understanding and improvement in equipment.	2
ORG04	2	2	4	Greater understanding and improvement in equipment. Advancement in technology.	3
FIN03	3	3	3	Innovative technology through continuous investment.	2
TEC06	3	3	4	Active team, which informs the possibility of failures, instead of being passive.	2

TEC04	3	3	3	Customer's perception of safety, which facilitates data collection and dashboard construction.	3
TEC03	3	2	3	Better data latency, fewer slowdowns, and more flexibility, thanks to good data management. It delights the customer.	3
TEC02	3	1	4	New business opportunities.	3
TEC05	3	1	3	Credible digital transformation.	2
TEC01	2	3	4	Company distinguishes itself as a pioneer in digitalization, in a way that customers come spontaneously to discover the company's solutions.	2
SC02	3	1	4	New business opportunities.	3
BUS01	3	3	4	Customer delight.	2
BUS02	3	3	4	Customer's value perception and improvement in customer's production.	2

Source – Created by the author

ID3_C3 provided some comments to justify her choices. However, not all barriers were commented in detail, given time the interview's time constraint.

The barriers which require the largest amount of time to be solved are STR02 (development and/or buy new competencies), ORG01 (culture shift, resistance/fear, and awareness), ORG03 (internal conflicts and silos), FIN03 (resource limitation and high investment), TEC02 (systems

for collaboration), TEC03 (systems for data collection and management), TEC04 (risks related to data and technology), TEC05 (technology high complexity), TEC06 (technology strategy), SC02 (collaboration and information sharing), BUS01 (recognition of market demand), and BUS02 (customer awareness and mindset).

As explained by ID3_C3 it takes a long time to overcome issues originated from the resistance, fear, and lack of awareness of the employees (ORG01): "*we have been dealing with these issues for three years*", and to surmount challenges in understanding the market demand (BUS01): "*we have an extensive experience in collaborating with clients and identifying what they ask for (...) However, the time spent is high, because we allocate one employee to monitor each client for around one year, to propose solutions in line with their needs*". Moreover, she mentioned that it takes a long time to increase customers' awareness and change their mindset (BUS02): "*it takes around one year and a half (...) some clients have difficulty in implementing digital solutions, for fear of having to make a major transformation internally*".

The barriers which require the largest amount of financial resources to be solved are ORG01, ORG03, FIN03, TEC01 (lack of technology, skills and understanding), TEC04, TEC06, SC02, BUS01, and BUS02. To overcome ORG01, ID3_C3 mentioned that the financial resources required are high and used for training and marketing, to exemplify she provided an example: *"we had to make a high investment in the creation of digital models that simulate clients' factories, to increase internal salespeople's understanding of the solution they were trying to sell"*. Moreover, according to her, to overcome the lack of technology, skills, and understanding (TEC01), the company already invested around five hundred thousand reais (R$) in training.

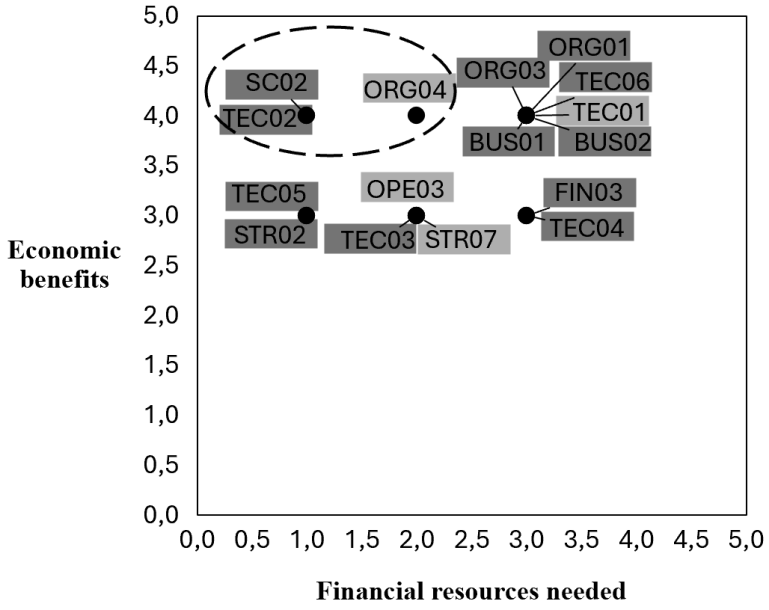
The barriers whose financial impact is expected to be extremely significant once they are solved are ORG01, ORG03, ORG04 (training and hiring), TEC01, TEC02, TEC06, SC02, BUS01, and BUS02. The financial return in overcoming TEC02 and SC02 is very high, as explained: "*the economic benefit is extremely high, as convincing clients to collaborate and share information is essential for selling the solution (...) if the maintenance personnel is resistant, I cannot collect the data. We must overcome the client's staff's fear of losing their jobs due to the adoption of our solution*". Moreover, she explained the economic benefits in better understanding the market demand (BUS01): "*the economic benefits are extremely high because it allows recurring revenue*".

Finally, the barriers with the highest grade for non-financial benefits once solved are STR02 and STR07 (lack of vision and understanding). That is because, by overcoming those issues, ID3_C3 expects the creation of new business opportunities, delivery optimization and increase

in products' value. Therefore, the positive impact combines present gains and future opportunities for the company and involve enhancement of internal procedures (delivery) and external perception (products' value).

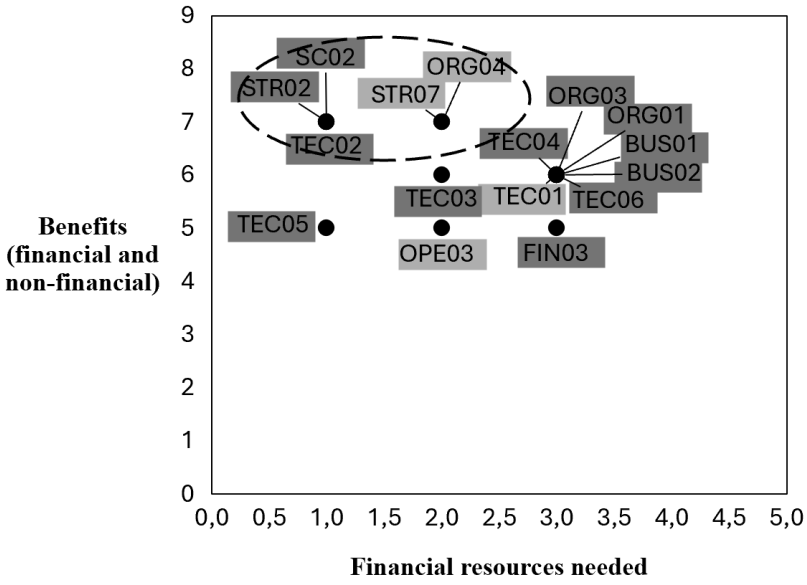
From the results shown in Table 11, it was possible to draw the Graphs 5 and 6. In Graph 5 financial resources are compared to financial benefits. In Graph 6 financial resources are compared to financial and non-financial benefits. In Graphs 5 and 6 the shade of the barriers' codes refers to the time required to overcome them. The darker the shade, the higher the amount of time needed.

Graph 5 – C3: Prioritization 1



Source – Created by the author

Graph 6 – C3: Prioritization 2



Source – Created by the author

For company 3, the most challenging barriers are the ones occupying the right side of the Graphs 5 and 6 and with the darkest shade: BUS01, BUS02, ORG01, ORG03, TEC04, TEC06, and FIN03. C3 should not overlook those barriers. However, they are not the company's priority in a short-time horizon, considering that there are barriers which are easier to overcome and provide better outcomes.

Indeed, the top-left quadrant is the one with the most promising barriers to start tackling, as they are less expensive to overcome, and have more positive impact once solved. Considering Graph 5, collaboration and information sharing (SC02), training and hiring (ORG04) and systems for collaboration (TEC02) occupy the top-left quadrant and should be the company's priority. By adding non-financial benefits into the analysis, as represented in Graph 6, other two barriers appear as priorities: development and/or buy new competencies (STR02) and lack of vision and understanding (STR07). Given that different amounts of time are required to solve the mentioned barriers, the company may choose to start investing in ORG04 and STR07, as they are the fastest to surmount, providing benefits earlier.

To overcome collaboration and information sharing (SC02) issues and problems related to systems for collaboration (TEC02), the company needs to invest time to convince its client's IT and Operations team to cooperate and adopt systems that allow the data flow required by C1 to provide its services. Even with low financial investments, the impact coming from solving those barriers are very positive in financial terms, as they are essential for selling C1's digital product-service solution. In ID3_C3's words: "*overcoming resistance from IT and the*

customer's Operations' team is essential to selling the solution". Moreover, as a non-financial benefit, new business opportunities were mentioned.

To overcome training and hiring (ORG04) issues, the company must deal with medium investments in terms of time and money, especially in the IT, AT, and After-sales departments. The financial returns expected are very high and non-financial benefits include greater understanding of the company's offers, improvement in equipment, and advancement in technology. Thus, it enhances the value delivered to customers and company's revenue, as employees are better hired and trained.

Indeed, C3 must invest in continuous training its employees, to allow them to develop the required competencies (STR02) and overcome their lack of vision and understanding (STR07). The cost of training is low, and the economic benefits are high, as explained by ID3_C3: "*when the technicians begin to use and understand the technology more, they become a salesperson, disseminating the technology and generating new business for the company. These are future opportunities and cost reduction with start-ups. Moreover, we save R$157,000 annually in travel costs given the digital transformation*.". Besides training, ID3_C3 mentioned the necessity of hiring, in some cases, new employees who already possess a clearer business vision and technology understanding.

4.4 Company 4 (C4) – Industrial machines and automation

4.4.1 Company's context and supply chain

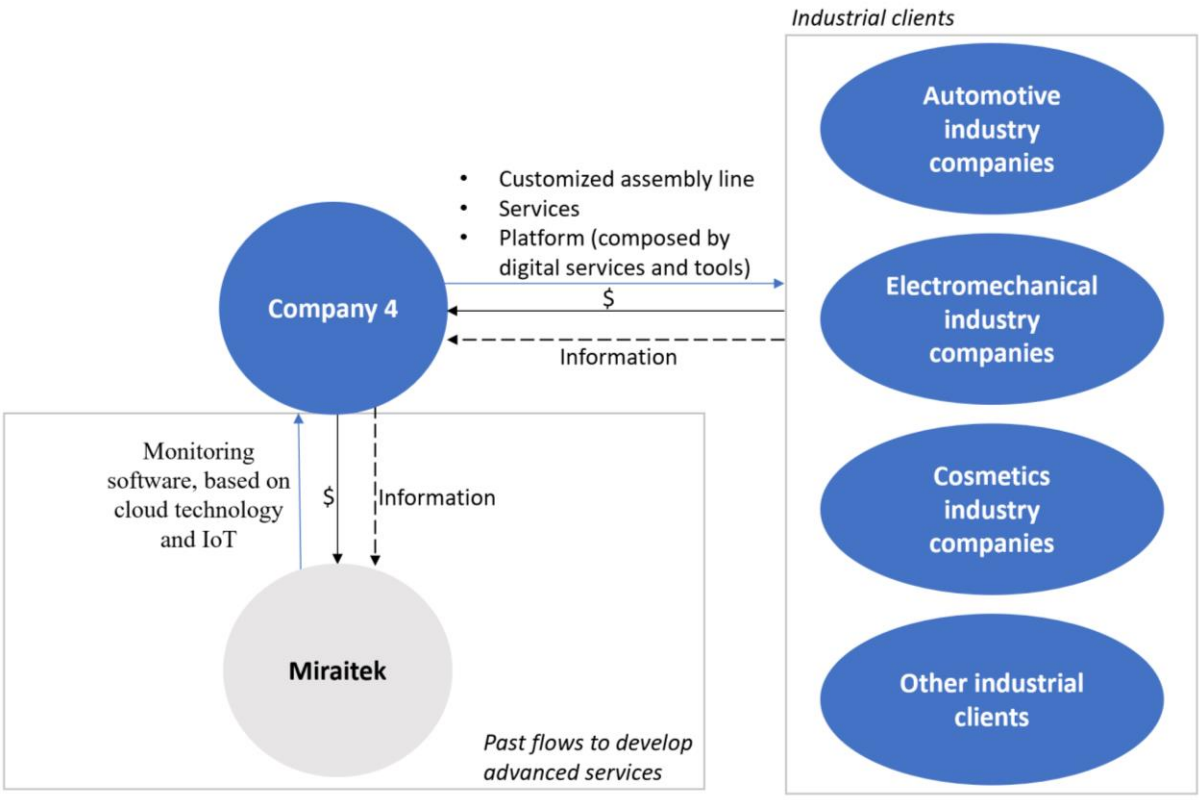
C4 is an Italian company specialized in designing and manufacturing customized assembly lines for various industries, with around seventy employees in Italy. From sixty to seventy per cent of its production is destined to the international market, specially to Germany, France, Spain, and Switzerland. It also has clients in Poland, Check Republic, Turkey, China, Morocco, Egypt, and South America.

The company creates tailored solutions to automate and streamline production processes, enhancing efficiency and quality control. Each project is designed according to a client's specifications, through Engineer to Order manufacturing method. The assembly lines are composed by customized machines, according to the principles of modularity and standardization. The machines are composed by separate modules, which perform specific steps in the assembling process (e.g., pick and place, stamping, among others) and are selected given the clients' needs.

Besides the sale of automated and customized assembly lines, C4 provides remote assistance for maintenance and sells a platform, composed by digital services and tools. One of the digital services is a real-time remote monitoring software integrated to the machines, based on cloud technology an IoT. This software allows clients to monitor the performance of their installed machines, in terms of efficiency, availability and quality of machine processing. The system also flags operation anomalies and identifies on which station the fault is occurring, helping interventions and, thus, reducing machines down time.

The monitoring software was developed in a partnership with Miraitek, a company originated from a spin-off of Politecnico di Milano, specialized in data science and artificial intelligence. Despite the joint development of the solution, the selling and service provision are entirely performed by C4. Thus, to offer the solution to its clients, the company does not have any partners or suppliers, which is represented in the supply chain scheme in Figure 7.

Figure 7 – Part of C4's supply chain



Source – Created by the author

According to ID4_C4's perception, it is not hard to sell the monitoring systems to clients who understand its importance and benefits, such as higher efficiency. However, he mentioned

that a constant effort is necessary to raise awareness among buyers who only look for the automated assembly line.

Moreover, some customers do not want to share data with C4, due to privacy policies. In this case, the monitoring system is restricted to the clients' access. However, most buyers understand that the data accessed by C4 help to improve the company's machines and services, enhancing customers satisfaction.

4.4.2 Barriers

ID4_C4 works as Innovation manager in C4. He identified six barriers for digital servitization within the organization, which are summarized in Table 12. Table 12 follows the model of "table A", explained in the intra-case analysis section in the methodology chapter.

Table 12 – C4: Barriers' identification and actors involved

Barrier	Code	Internal or external	Departments or actors involved	Number of departments/ actors involved
Development and/or buy new competencies	STR02	External	Miraitek (spin-off of Politecnico di Milano)	1
Capability to communicate and sell the offer	OPE03	Internal	Sales	1
Profitability	FIN01	Internal	Sales, Costs' control	2
Collaboration and information sharing	SC02	External	Client's Industrialization team, Client's Data analysis team	2
Customer awareness and mindset	BUS02	External	Client's Top management	1
Country specific	BUS06	External	China	-

Source – Created by the author

From the barriers identified, four were classified as external and two as internal. The company's departments related to the internal barriers are Sales and Costs' control. Sales was mentioned twice, and Costs' control only once. The external actors mentioned were clients' Industrialization and Data analysis teams, the top management, and Miraitek, with which the company has a partnership for the development of new competencies. Each external actor was mentioned once.

Additionally, it can be noticed that no barriers have a high number of actors involved, only profitability and collaboration and information sharing have two agents each. Comparing both, collaboration and information sharing may need a higher coordination effort, as it is related to external actors, which are more distant from the company's control.

Moreover, on country-specific barriers, ID4_C4 mentioned that clients from countries with a high diffusion of advanced technology, such as Germany, are easily convinced to adopt digital solutions. However, clients from countries whose technology adoption and automation are not yet well diffused, are harder to convince.

Besides that, ID4_C4's perception on barriers' strength and impact was registered and the results are shown in Table 13. Table 13 follows the model of "table B", explained in the intra-case analysis section in the methodology chapter.

Table 13 – C4: Barriers' strength and impact

"0" – not relevant; "4 – very high importance"

Barrier	Strength		Impact	
Code	Time	Financial resources	Financial benefits	Non-financial benefits
STR02	3	2	3	4
OPE03	2	1,5	3	0
FIN01	3	1	3	0
SC02	3	1	2	2
BUS06	4	4	4	3
BUS02	4	2	4	2

Source – Created by the author

The barriers whose solutions require very high amounts of time are BUS02 (customer awareness and mindset), and BUS06 (country specific). In ID4_C4's understanding: '*it takes more than one year to build customer awareness and mindset (BUS02), being necessary to*

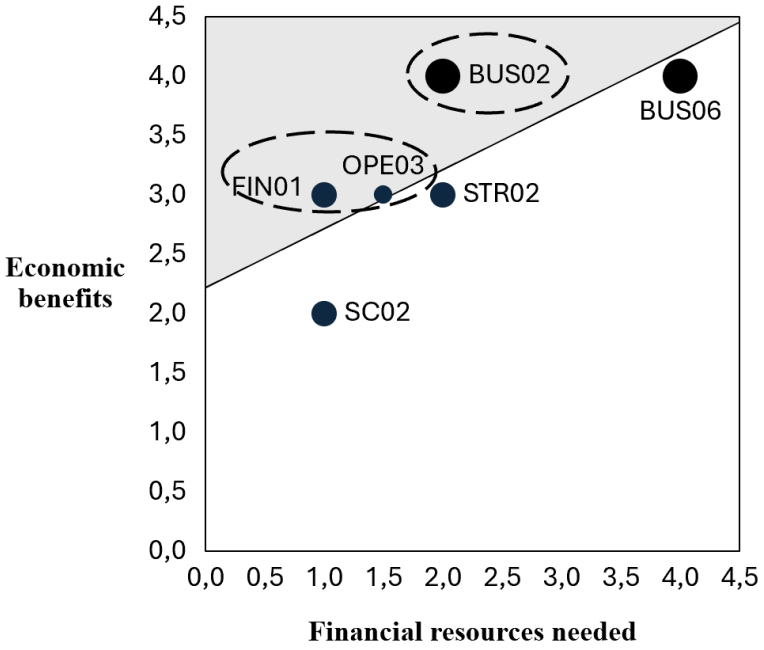
invest in communication". Moreover, when discussing country specific issues, ID4_C4 mentioned that "*the Chinese market currently demands basic automation technologies, not yet asking for digital servitization solutions (...) it does not occur because of a lack of infrastructure, but because of low customer awareness and mindset. To overcome this issue, it might take some years, and it is necessary to invest in communication and increase the company's presence in technology fairs in China*".

As many years of investment and presence in fairs are required to overcome country specific barriers (BUS06), ID4_C4 believes that very high financial resources are needed. He also believes that this high investment will result in significant financial returns for the company, as "*it allows to acquire big new markets"*. Expressive economic benefits are also expected from solving BUS02, as explained by ID4_C4: "*If you can change the mindset and awareness, there is the possibility to acquire more clients and market share. It is not only the mindset of our clients, but of all potential clients*".

The only barrier whose solution would generate very high non-financial benefits is STR02 (development and/or buy new competencies). The benefits identified by ID4_C4 are brand consolidation and the possibility of offering further value to clients, beyond C4 industrial plants.

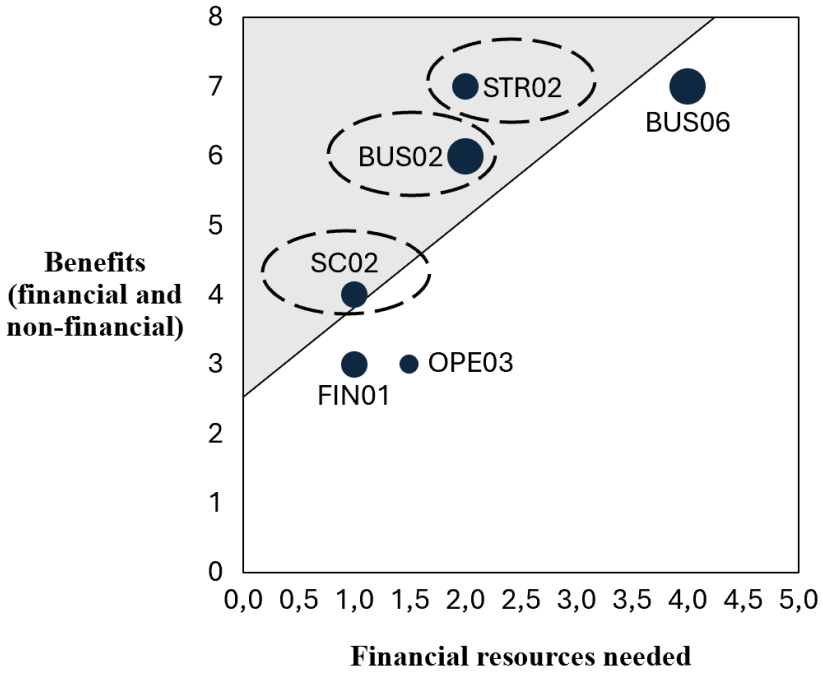
From the results shown in Table 13, it was possible to draw the Graphs 7 and 8. In Graph 7 financial resources are compared to financial benefits. In Graph 8 financial resources are compared to financial and non-financial benefits. In Graphs 7 and 8 the dots' size refer to the time required to overcome barriers. The larger the dot, the higher the amount of time needed.

Graph 7 – C4: Prioritization 1



Source – Created by the author

Graph 8 – C4: Prioritization 2



Source – Created by the author

From the results displayed in the Graphs 7 and 8, it can be observed that BUS06 (country specific) issue is the most challenging for company 4, as it is further positioned in the right side of the graph, meaning it requires a significant investment, and is among the barriers with the largest dot, which means that a high amount of time is required to overcome it.

Moreover, by plotting the points in Graphs 7 and 8, it is possible to notice that no barriers are clearly positioned in the top-left quadrant, as high impacts are accompanied by high financial investments. In this case, to identify priorities, linear trend lines were drawn. The barriers whose position is above and to the left in comparison to the trend lines were classified as the priorities, as with the same financial investment, they provide better outcomes in comparison to the average.

Additionally, when comparing the results from both graphs, the prioritized barriers for C4 are not the same when non-financial benefits are included in the impact index, except from the challenges associated with customer awareness and mindset (BUS02). This occurs because the issues related to the capability to communicate and sell the offer (OPE03) and profitability (FIN01) do not offer non-financial benefits once solved, according to ID4_C4. On the other hand, the non-financial benefits are expected to be very high for development and/or buy new competencies (STR02). Moreover, even if the impact is moderate for solving collaboration and information sharing issues (SC02), it is relatively easy to overcome this challenge, as explained by ID4_C4: "*It takes about one year to overcome issues of collaboration and information sharing with clients. The expenses are low, as no specific resources are needed*". Thus, this barrier is also present in the priority area in Graph 8.

To tackle BUS02, ID4_C4 recognized the need to invest in communication. The economic benefits are significant, as explained: "*If you can change the mindset and awareness, there is the possibility to acquire more clients and market share. It is not only the mindset of our clients, but of all potential clients*". Other benefits include the consolidation of partnerships with clients and loyalty.

To solve STR02, the company has to invest in the development of new competencies. In ID4_C4's words: "*it takes about one year for the development of new competencies and the investment in the first year is from one hundred thousand to two hundred thousand euro*". In the case of the competencies developed for the provision of the new servitized offer, for instance, the expenses came from hiring Miraitek services and costs with internal employees working in the project. The economic returns form this investment were high, as many clients have bought the service of remote monitoring.

Moreover, to develop the capability to communicate and sell the offer (OPE03): "*it takes some months, and it is necessary to invest to redesign how things are done internally*". The economic benefits are high, as C4 can acquire new market share. Other benefits are related to brand consolidation. Finally, to define prices and costs, impacting the profitability (FIN01): "*it requires around one year and low financial investment, related to internal management*".

4.5 Cross-case analysis and general considerations

In this section the results obtained in the intra-cases analysis of C1, C2, C3, and C4 are confronted, allowing to understand similarities and differences, and to create general considerations.

4.5.1 Context and supply chain

Interestingly none of the companies investigated recurred to external actors to jointly provide the DPSS offering to their clients, even if C3 and C4 partnered with technology expert companies to develop their advanced solutions. The motivation behind the choice of vertical integration varies among companies. Lack of qualified players in the market and desire to preserve the autonomy were mentioned as motivations for C1 and C3 respectively.

Moreover, from the interviewees' considerations, the Brazilian market, where C1, C2, and C3 are inserted, and where C4 has a branch, seem not yet mature in the adoption of DPSS. This can be noticed by the lack of qualified players/partners in C1's case. Moreover, ID1_C1 mentions that even if Brazilian customers are aware of the need for basic maintenance, selling additional, more advanced services, can be challenging, given the low financial "freedom" of clients. Similarly, ID3_C3 stated that many customers are still not actively looking for Industry 4.0 solutions.

In addition, ID2_C2 mentioned the existence of obstacles in Brazil, due to a lack of a modern IT infrastructure. Indeed, in some cases, C2 could not sell its offering because the potential client had a very old version of Windows, in which C2's software was not programmed to work: "*here, there are people working with Windows 10, so it (the software) doesn't work*".

However, even if not mature, the interviewees recognize that the DPSS' adoption in Brazil is increasing, with the augment of awareness among clients. Indeed, ID3_C3 mentions that, despite some initial resistance, when clients understand the benefits provided by TED-D (the advanced offering sold by C3), they welcome the solution. Such benefits can be proved by measuring the offering's performance and savings, as stated by ID1_C1: "*the measurement of the benefits is essential for convincing clients.*".

Additionally, by increasing partners competencies, maturity, training, and awareness, ID2_C2 expects to "*increase supply chain visibility, in terms of data, connecting all the links*

in the value chain.". This new approach towards sharing data in the supply chain can significantly enable the development of new DPSS and its adoption by different players.

4.5.2 Barriers

4.5.1.1 Occurrence and strength

From the barriers' list made through the literature review, summarized in Table 1, the interviewees from the companies C1, C2, C3 and C4 identified ten, thirteen (counting FIN01A and FIN01B as FIN01), sixteen and six barriers respectively, which are listed in Table 14. The barriers that appear in all interviews are capability to communicate and sell the offer (OPE03) and customer awareness and mindset (BUS02). Moreover, development and/or buy new competencies (STR02), risks related to data and technology (TEC04) and country specific barriers (BUS06) appear in three out of four interviews.

Considering risks related to data and technology (TEC04), it can be noticed that it only appeared for companies mainly inserted in Brazil, and the challenges referred to data security. This can be due to the fact that data protection laws are more mature in Europe, increasing the safety and reassuring clients. In fact, GDPR (General Data Protection Regulation) is more established and stringent compared to the LGPD (Lei Geral de Proteção de Dados). GDPR, launched in May 2018 in the European Union, imposes strict regulations with hefty fines for non-compliance, fostering a high standard of data protection globally. While LGPD, enacted in August 2018 in Brazil and fully effective since September 2020, mirrors GDPR principles but may not be as rigid in enforcement and fines (MARTINS, 2023).

Table 14 – Cross-case: Summary of barriers and categories identified

1 - Barrier identified in the interview

Level 2	Code	C1	C2	C3	C4	Sum	Sum by category
Risks related to data and technology	TEC04	1	1	1		3	11
Lack of technology, skills and understanding	TEC01		1	1		2	
Systems for data collection and management	TEC03	1		1		2	
Technology strategy	TEC06		1	1		2	

Systems for collaboration	TEC02			1		1	
Technology high complexity	TEC05			1		1	
Customer awareness and mindset	BUS02	1	1	1	1	4	10
Country specific	BUS06	1	1		1	3	
Recognition of market demand and market acceptance	BUS01			1		1	
Regulations	BUS03	1				1	
Economic changes	BUS04	1				1	
Development and/or buy new competencies	STR02		1	1	1	3	7
Servitized offer cannibalizing physical products	STR09	1	1			2	
Changing/complex business models and methods	STR06		1			1	
Lack of vision and understanding	STR07			1		1	
Capability to communicate and sell the offer	OPE03	1	1	1	1	4	6
Support and service delivery	OPE01	1				1	
Measurement of performance and savings	OPE04	1				1	
Training and hiring	ORG04		1	1		2	4
Culture shift, resistance/fear and awareness	ORG01			1		1	
Internal conflicts and silos	ORG03			1		1	
Profitability and pricing	FIN01		1		1	2	4
Financial risks and cash flows	FIN02		1			1	
Resource limitation and high investment	FIN03			1		1	
Collaboration and information sharing	SC02			1	1	2	3
Partners competencies, maturity, training, and awareness	SC04		1			1	

Source – Created by the author

Moreover, by analyzing categories, as displayed in Table 14, it is possible to notice that technological and business-related barriers are the most frequently mentioned. However, this number should be considered carefully, as it is affected by how the barriers where originally grouped. Additionally, environmental barriers were not identified by any interviewee.

Besides identifying barriers, the interviewees classified their strength and impact. Therefore, it was possible to understand which barriers are the most challenging and the ones more beneficial once solved.

The most challenging barriers are the ones which require the companies to invest the highest financial and time resources, as identified in Table 15 and 16. These tables only display barriers named by more than one company, to allow the comparison of different considerations on the same barrier. For company 2 (C2), the grades considered for FIN01 are the average of the grades of FIN01A and FIN01B.

Table 15 – Cross-case: Financial resources needed to overcome barriers

"0" – not relevant; "4 – very high importance"

Level 2	Code	C1	C2	C3	C4
Country specific	BUS06	2.5	4		4
Customer awareness and mindset	BUS02	1	0	3	2
Systems for data collection and management	TEC03	1.5		2	
Risks related to data and technology	TEC04	1	1	3	
Lack of technology, skills and understanding	TEC01		1	3	
Technology strategy	TEC06		0	3	
Capability to communicate and sell the offer	OPE03	1	2	2	1.5
Servitized offer cannibalizing physical products	STR09	0	3		
Development and/or buy new competencies	STR02		1	1	2
Training and hiring	ORG04		2	2	
Profitability and pricing	FIN01		2		1
Collaboration and information sharing	SC02			1	1

Source – Created by the author

Table 16 – Cross-case: Time resources needed to overcome barriers

"0" – not relevant; "4 – very high importance"

Level 2	Code	C1	C2	C3	C4
Country specific	BUS06	4	4		4
Customer awareness and mindset	BUS02	2	4	3	4
Systems for data collection and management	TEC03	4		3	
Risks related to data and technology	TEC04	1	2	3	
Lack of technology, skills and understanding	TEC01		4	2	
Technology strategy	TEC06		4	3	
Capability to communicate and sell the offer	OPE03	1	2	2	2
Servitized offer cannibalizing physical products	STR09	1	4		
Development and/or buy new competencies	STR02		2	3	3
Training and hiring	ORG04		3	2	
Profitability and pricing	FIN01		3		3
Collaboration and information sharing	SC02			3	3

Source – Created by the author

From tables 15 and 16, it is possible to notice that country specific barriers (BUS06) are the most expensive and time consuming to overcome for companies C1, C2 and C4. In this context, depending on the country, C1 faces challenges related to culture, with clients not being interested in digital solutions, and infrastructure, with lack of proper internet connection and availability of energy; C2 deals with barriers related to the poor adoption of advanced technologies; and C4 faces low customer awareness and mindset, as clients are not asking for digital servitization solutions. Therefore, they must invest in infrastructure and marketing efforts for extended periods of time, to create the basis for their operation, surmount cultural challenges, and increase their presence in other localities.

It is also interesting to observe that there are barriers which are perceived very differently among companies, such as servitized offerings cannibalizing physical products (STR09). This barrier is significant for C2, taking around one year and one million of reais (R$) to plan and avoid losses with the new offering. On the other hand, for C1, it takes about weeks and no additional financial resources to discuss the launch of new offerings and their impact on

the current portfolio, to avoid cannibalization. That is because these meetings are part of the C1's standard protocol. In this way, it is evident that the consolidation of best practices internally, with the adoption of standard procedures, can help companies to navigate the complexity of the new business model.

4.5.1.2 Benefits

Tables 17 and 18 consolidate the economic and non-economic benefits expected from C1, C2, C3 and C4. These tables only display barriers identified by more than one company, to allow the comparison of different considerations on the same barrier.

Table 17 – Cross-case: Economic benefits

"0" – not relevant; "4 – very high importance"

Level 2	Code	C1	C2	C3	C4
Capability to communicate and sell the offer	OPE03	3	4	3	3
Training and hiring	ORG04		4	4	
Profitability and pricing	FIN01		4		3
Lack of technology, skills and understanding	TEC01		3	4	
Technology strategy	TEC06		2	4	
Risks related to data and technology	TEC04	3.5	1	3	
Systems for data collection and management	TEC03	2		3	
Country specific	BUS06	2.5	4		4
Customer awareness and mindset	BUS02	2	2	4	4
Servitized offer cannibalizing physical products	STR09	2.5	4		
Collaboration and information sharing	SC02			4	2
Development and/or buy new competencies	STR02		2	3	3

Source – Created by the author

Table 18 – Cross-case: Non-economic benefits

"0" – not relevant; "4 – very high importance"

Level 2	Code	C1	C2	C3	C4
Capability to communicate and sell the offer	OPE03	3	4	2	0
Training and hiring	ORG04		4	3	

Profitability and pricing	FIN01		4		0
Lack of technology, skills and understanding	TEC01		1	2	
Technology strategy	TEC06		3	2	
Risks related to data and technology	TEC04	3	0	3	
Systems for data collection and management	TEC03	3		3	
Country specific	BUS06	3	4		3
Customer awareness and mindset	BUS02	2	3	2	2
Servitized offer cannibalizing physical products	STR09	3	4		
Collaboration and information sharing	SC02			3	2
Development and/or buy new competencies	STR02		0	4	4

Source – Created by the author

From Table 17, it is possible to notice that the companies which identified having the barriers OPE03, ORG04, FIN01 and TEC01, agree that they generate high or very high economic benefits once solved. Moreover, solving BUS02 would generate very high economic benefits for C3 and C4, and surmounting BUS06 would have very significant economic benefits for C2 and C4.

From Table 18, it can be observed that the companies which identified having the barriers ORG04, TEC03, BUS06, and STR09, agree that they generate high or very high non-economic benefits once solved. Moreover, solving TEC04 and TEC03 would generate high non-economic benefits for C1 and C3, and surmounting STR02 would have very significant non-economic benefits for C3 and C4

However, there are some barriers that once solved generate financial and non-financial outcomes whose significance largely differs from one company to another. That is the case of solving risks related to data and technology (TEC04). Despite its high economic and non-economic importance for C1 and C3, C2 would not be significantly benefited. That is because C2 have already addressed risks related to data and technology in the past, and has this topic mainly covered. Through this example, it can be perceived that the barriers' prioritization method proposed in this thesis should be utilized throughout the time, allowing companies to update the barriers' importance, and tackle changing priorities.

4.5.1.3 Priorities

The barriers that should be prioritized are the ones that are relatively cheap and fast to overcome and have the most significant expected benefits. The prioritized barriers by company are displayed in Table 19.

Table 19 – Cross-case: Summary of prioritized barriers

1: Barrier identified in the interview; P: Barrier prioritized

Level 2	Code	C1	C2	C3	C4	"P" sum
Capability to communicate and sell the offer	OPE03	P	P	1	P	3
Measurement of performance and savings	OPE04	P				1
Profitability and pricing	FIN01		P		P	2
Training and hiring	ORG04		1	P		1
Servitized offer cannibalizing physical products	STR09	P	1			1
Lack of vision and understanding	STR07			P		
Development and/or buy new competencies	STR02		1	P	P	2
Risks related to data and technology	TEC04	P	1	1		1
Systems for collaboration	TEC02			P		1
Coordination and information sharing	SC02			P	P	2
Customer awareness and mindset	BUS02	1	1	1	P	1

Source – Created by the author

From Table 19, it is possible to observe that the challenge related to the capability to communicate and sell the offer (OPE03) was prioritized by three out of four companies, showing its high importance. By tackling this issue, companies invest few resources and have high benefits, helping them in the successful implementation of DPSS.

5 CONCLUSIONS AND CONTRIBUTIONS

This research aimed to identify, categorize, and prioritize the main challenges faced by organizations in implementing digital servitization. The relevance of this subject is connected to the growing adoption of this business model, as it enables more customizable, flexible, and time-efficient services to customers, and better image, customer lifetime value and profitability to companies (VENDRELL-HERRERO et al., 2017).

In the present thesis, the challenges found in the literature were consolidated in a list and divided into categories, facilitating their identification and understanding by practitioners. The categories derived, in a first moment, from the classification of servitization related benefits and challenges presented in KAMAL et al., 2020, which includes six dimensions: Strategy, Organization, Operational, Financial, Technological and Environmental. To the categories presented in their work, this thesis added two other main categories, namely Business Context and Supply Chain, to collect barriers not previously comprised.

In the four case studies conducted, the barriers' list created was tested, being used as a guide to identify obstacles faced by firms through interviews. The great correspondence of barriers from the list and the ones uncovered by the interviews demonstrated the broad collection of challenges spotted in the bibliographic research. Besides the challenges, supply chain actors were identified in the four case studies. Interestingly, vertical integration was performed by all of them, even if technology expert partners co-developed the solutions offered by companies 3 and 4.

Moreover, this work briefly discussed particularities from the Brazilian scenario, where the organizations interviewed are inserted or have branches. Thus, the growing awareness of DPSS among Brazilian customers and players in the market was mentioned, despite some resistance and obstacles in the technological infrastructure. In addition, given the sensitivity in dealing with clients' data, it was hypothesized that a more stringent data legislation could help in reassuring clients to collaborate. In this way, this thesis contributed to answer KAMAL et al., 2020's proposition to investigate digital servitization practices in emerging economies, giving their increasing significance and low attention in the literature.

Besides that, this work proposed a prioritization method for barriers, using empirical evidence. Such prioritization is still emergent in the literature, as WEERABAHU et al., 2022 states that their work was the first one to attempt to prioritize barriers to digital servitization in the manufacturing sector with empirical evidence. In contrast to their work, this thesis considered the expected benefits and the time and financial resources needed to overcome the

barriers, while WEERABAHU et al., 2022 focused on the barriers' overall influence in terms of their relationship with other factors and/or barriers, and causal relationships.

Finally, from the intra-case and cross-case analysis, it was possible to notice that country specific barriers (BUS06) are very challenging for companies implementing DPSS as their business model, and that tackling the challenge related to the capability to communicate and sell the offer (OPE03) is of ultimate importance for practitioners.

Indeed, three out of four companies interviewed identified BUS06 as the most expensive and time-consuming barrier to overcome. Besides its intrinsic difficulty, the interviewees' agreed on the high potential for economic benefits after solving this barrier. Likewise, three out of four companies prioritized solving the issue related to the capability to communicate and sell the offer (OPE03), which requires less resources and provides better outcomes in comparison to the average.

The limitations of this work include the low number of firms interviewed, which hinders the generalization of the conclusions and a deeper understanding of the Brazilian scenario. Moreover, the thesis could have integrated to the prioritization method causal relationships among barriers, as suggested in WEERABAHU et al., 2022. Such relationships were not explored, given the short available time of some practitioners interviewed.

Despite the limitations mentioned above, the research still suggests interesting insights for organizations seeking to adopt digital servitization. Future studies could further enhance the understanding of the challenges and potential solutions associated with implementing this business model, especially in emerging countries. Moreover, future works, could improve the prioritization method proposed, by combining it to the method suggested in WEERABAHU et al., 2022, or to other complementary dimensions, helping practitioners and decision-makers to make more informed choices and devise more effective strategies.

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APENDIXES

APENDIX A – Interview guide

1 Self-introduction and presentation of main concepts and examples

First, I would like to thank you for your availability and assure you the confidentiality of the interview. My name is Beatriz, and I am working on my final thesis focusing on digital servitization. I proposed this interview to learn more about your company and to better understand the main challenges and barriers you have faced throughout the adoption of digital servitization.

Servitization requires a company to provide a form of service together with its products. For instance, services may include maintenance, repair, overhaul and asset support, enabled with remote monitoring and diagnostic capabilities. Moreover, advanced services can be offered by contractual agreements in which the customer does not purchase the resource but pays for the use of the product or per unit of service provided by the resource, such as leasing, pay-for-use, and performance agreements.

Digital servitization transforms conventional Product-Service Systems (PSS) into Smart PSS, a value co-creation business strategy driven by IT. This evolution is facilitated by technologies such as the Internet of Things (IoT), data analytics, and cloud computing. For example, connected devices can gather extensive data on various activities, enabling the transition to Smart PSS through machine learning and statistical analysis.

2 Company context and supply chain

- To start our conversation, could you introduce yourself and present the company?
- Considering the definition of digital servitization provided in the introduction, would you define it in a different way?
- Has the company always adopted digital servitization or implemented it later? What was the reason behind it? Was it internally promoted or resulted from the pression of an external actor (which actor)?

- Can you name and explain the product-service bundles offered by your company? If possible, can you send me a formal document with the portfolio of the offerings named by you?
- How do you market these offerings? Does the client actively ask for it?
- Who are the main suppliers and partners you work with? And clients?
- How is the relationship of the company with those actors in terms of: exchange of competencies and interdependency?

3 Barriers

During the company's journey, what were the challenges to the adoption of digital servitization in terms of (if possible, refer to the product-bundle offer associated to the challenge):

- Business Context challenges
- Strategical challenges
- Financial challenges
- Operational challenges
- Organizational challenges
- Technological challenges
- Supply Chain challenges
- Environmental challenges

4 Mapping the company's ecosystem and formalizing barriers

- First moment: Now I would like to map with you the company's ecosystem. To do that it is important to consider the customers, focal company, component suppliers, and complementarians, who are key partners and possess different skills needed to deliver the product-service offering.
- Second moment: To formalize the barriers mentioned by you, I would like to show you a list I have created while you were providing examples of challenges faced by

your company. Do you believe this list is coherent and complete? Would you like to complement it with other challenges?

5 Prioritization of the challenges named by the interviewee (barriers' strength and impact on performance)

For each challenge mentioned by you, I would like to fill the following table:

	Responsibilities/ Influence		**Barrier's strength**		**Barrier's impact on performance**	
Barrier	Internal/ External?	Department/ Actors involved?	Managerial time?	Financial resources?	Financial benefits?	Non-financial benefits?
#1						
#2						

5.1 Responsibilities and influence

- Would you classify it as an internal challenge (which solely depends on the company's decisions and is under its control) or external challenge (which depends on the action of external actors)?
- If internal, what are the departments involved (ex: supply chain, HR…)? If external, what are the actors involved (ex: supplier, client…)?

5.2 Strength of barriers

How hard would it be to overcome each challenge in terms of:

- Managerial time?
- Financial resources?

5.3 Barriers' impact on performance

How do you evaluate the benefits associated with the elimination of each challenge in terms of:

- Financial benefits?

- Non-financial benefits?

6 Conclusion

If there are any additional points, please feel free to add them. I would like to assure you once again the confidentiality of the interview and thank you for your availability. Moreover, if you would like, I can send you the transcription of the interview by e-mail.

APENDIX B – Barriers of digital servitization implementation references

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