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# PRODUCT-CENTRIC SERVITIZATION JOURNEY IN A TRANSPORT ASSET COMPANY AND COMPLEX PRODUCT MANUFACTURER: ANALYSIS OF A CONCEPTUAL FRAMEWORK ON DIGITAL TECHNOLOGIES AND CAPABILITIES

Florianópolis, 2024

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Dissertation submitted to the Postgraduate Program in Production Engineering at the Federal University of Santa Catarina to obtain the Master's Degree in Production Engineering.

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Esse trabalho é dedicado à minha mãe
Maria Cândida e ao meu pai Altevir Italo.

## ABSTRACT

Servitization has become a key strategy for manufacturing companies seeking to differentiate themselves and gain a competitive edge. Driven by competitiveness, client demand, and economic considerations, manufacturers are increasingly integrating services into their offerings. The traditional approach of adding services to products to create product-service systems (PSS) is now being enhanced by incorporating digital technologies, which facilitate service innovation and the development of intelligent, connected products. The rapid advancement of digital technologies, such as AI, IoT, and digital platforms, is transforming the landscape of servitization, making it essential for companies to develop new capabilities to remain competitive. Despite the recognized convergence of digitalization and servitization, there is a significant gap in understanding their relationship. This includes identifying the critical combinations of digital technologies and capabilities necessary for successful digital servitization in product-centric manufacturers. In this sense, this dissertation characterizes the phenomenon of digital servitization in a product-centered manufacturing environment, underlying the relationships between digital technologies and capabilities that emerge in this context. Firstly, in order to understand the research problem and to identify and analyze alternative product-oriented servitization trajectories, a literature review and study case were conducted. Secondly, to identify and summarize the patterns in recent literature in the field of digital servitization, with a focus on evaluating emerging capabilities and digital technologies, a systematic literature review was carried out and a conceptual framework was built. Lastly, a field study with a second case study was conducted, which aimed to verify the relations in the conceptual framework and Evaluate how the relationship between digital technologies and capabilities applies in a product-centered industry focused on digital servitization. The findings suggest that clarity on the dynamics of digital technologies and capabilities relationships support companies to adopt or adapt their strategies, supporting their decision-making process. It also shows that the emergence of digital servitization necessitates the development of new organizational capabilities. Capabilities categories such as being data-driven organization, having technology integration, processes of service design in place, or even insurance of customer integration in the development of new PSSs, have shown to be crucial for successfully transitioning from product-centric to service-centric models. The categorization of digital technologies and capabilities, illustrating their distinct functionalities and strategic integration potential are enablers for managers to better design company's servitization strategy. Even though digital servitization enables innovation across various industries by optimizing operations and enhancing value offers, barriers were identified such as security issues, system upgrades, and organizational cultural changes that need addressing for successful technology implementation. It is recommended that for future research a quantitative approach for the relationships concluded of this research is performed, allowing to provide more robustness to the results. Yet, for further future research, a cross-industry analysis would allow generalization of results and the direction of deep-dive and proposition for taxonomy in different levels related to digital technologies and capabilities are also a need, considering the constant emerging new terms in the field of digital servitization.



**Key-words:** Digital servitization; digital technologies; capabilities.

## RESUMO

A servitização tornou-se uma estratégia fundamental para as empresas de manufatura que buscam se diferenciar e obter vantagem competitiva. Impulsionados pela competitividade, pela procura de novos clientes e por fatores econômicos, os fabricantes estão cada vez mais a integrar serviços nas suas ofertas. A abordagem tradicional de adicionar serviços a produtos para criar sistemas de produtos-serviços (PSS) está agora melhorando através da incorporação de tecnologias digitais, que facilitam a inovação de serviços e o desenvolvimento de produtos inteligentes e conectados. O rápido avanço das tecnologias digitais, como a IA, a IoT e as plataformas digitais, está a transformar o cenário da servitização, tornando essencial que as empresas desenvolvam novas capacidades para se manterem competitivas. Apesar da reconhecida convergência entre digitalização e servitização, existe uma lacuna significativa na compreensão da sua relação. Isto inclui identificar as combinações críticas de tecnologias e capacidades digitais necessárias para uma servitização digital bem-sucedida em fabricantes centrados em produtos. Neste sentido, esta dissertação caracteriza o fenômeno da servitização digital num ambiente de produção centrado no produto, subjacente às relações entre tecnologias e capacidades digitais que emergem neste contexto. Primeiramente, a fim de compreender o problema de pesquisa e identificar e analisar trajetórias alternativas de servitização orientada a produtos, foram realizadas uma revisão da literatura e um estudo de caso. Em segundo lugar, para identificar e resumir os padrões da literatura recente no domínio da servitização digital, com foco na avaliação das capacidades emergentes e das tecnologias digitais, foi realizada uma revisão sistemática da literatura e construído um quadro conceitual. Por fim, foi realizado um estudo de campo com um segundo estudo de caso, que teve como objetivo verificar as relações no quadro conceitual e avaliar como a relação entre tecnologias e capacidades digitais se aplica em uma indústria centrada no produto com foco na servitização digital. Os resultados sugerem que a clareza sobre a dinâmica das relações entre tecnologias e capacidades digitais apoia as empresas na adoção ou adaptação das suas estratégias, suportando o seu processo de tomada de decisão. Mostra também que o surgimento da servitização digital exige o desenvolvimento de novas capacidades organizacionais. Categorias de capacidades como ser uma organização orientada por dados, ter integração tecnológica, processos de design de serviços implementados ou mesmo garantir a integração do cliente no desenvolvimento de novos PSSs, mostraram-se cruciais para a transição bem-sucedida de uma abordagem centrada no produto para uma abordagem centrada no serviço. A categorização das tecnologias e capacidades digitais, ilustrando as suas distintas funcionalidades e potencial de integração estratégica são facilitadores para que os gestores desenhem melhor a estratégia de servitização da empresa. Embora a servitização digital permita a inovação em vários setores, otimizando as operações e melhorando as ofertas de valor, foram identificadas barreiras, tais como questões de segurança de dados, atualizações de sistemas e mudanças culturais organizacionais que precisam de ser abordadas para uma implementação tecnológica bem-sucedida. Recomenda-se que para pesquisas futuras seja realizada uma abordagem quantitativa para as relações identificadas nesta pesquisa, permitindo dar mais robustez aos resultados. Uma análise intersetorial permitiria a generalização dos resultados e a direção do aprofundamento e proposição de taxonomia em diferentes níveis relacionados às tecnologias e capacidades digitais também é uma necessidade, considerando o constante surgimento de novos termos no campo da servitização digital.



**Palavras-chave:** Servitização digital; tecnologias digitais; capacidades.

# RESUMO EXPANDIDO

## Introdução

A servitização é uma estratégia que tem se destacado entre empresas de manufatura que buscam diferenciação e vantagem competitiva no mercado. Essa abordagem consiste em adicionar serviços à oferta de produtos, criando sistemas produto-serviço (PSS), o que representa um modelo de negócios mais complexo e potencialmente lucrativo (Visnjic & Van Looy, 2012; Favoretto et al., 2022). As motivações para a adoção da servitização variam desde demandas dos clientes até questões de competitividade e complexidade dos produtos, impulsionando as empresas a desenvolverem novos modelos operacionais (Raddats et al., 2015; Tronvoll et al., 2020). A transição para um modelo de serviços exige que os fabricantes reorientem seu foco, tradicionalmente voltado ao produto, para uma visão onde o serviço é um componente central da estratégia de negócios (Raddats et al., 2015). Recentemente, a servitização digital tem ganhado relevância como uma extensão da servitização, impulsionada pela digitalização e pela Indústria 4.0, que facilitam a integração de tecnologias digitais, como IoT, IA e plataformas digitais, aos produtos e serviços oferecidos pelas empresas de manufatura (Vilkas et al., 2021). Essa convergência entre digitalização e servitização permite o desenvolvimento de novas capacidades organizacionais e modelos de negócio inovadores, que são fundamentais para a competitividade no mercado global. A literatura recente aponta para a necessidade de investigar as relações entre tecnologias digitais e a evolução dos sistemas produto-serviço, especialmente considerando as combinações de capacidades e tecnologias que podem levar ao sucesso na servitização digital (Favoretto et al., 2022; Paschou et al., 2020). A relevância desse tema se intensifica com a demanda de indústrias centradas no produto que, em um cenário cada vez mais competitivo, precisam evoluir e adaptar suas ofertas para incluir serviços digitais que proporcionem maior valor agregado e novas fontes de receita (Langly, 2022). No entanto, ainda há lacunas significativas na literatura sobre a compreensão dessa transição digital e suas implicações para os fabricantes. Em resposta a essas lacunas, esta pesquisa visa aprofundar o entendimento das interações entre tecnologias digitais e capacidades necessárias para a servitização digital, buscando contribuir para a literatura e oferecer suporte prático para as empresas no processo de tomada de decisão.

## Objetivos

O objetivo principal desta pesquisa é caracterizar o fenômeno da servitização digital em um contexto de manufatura centrado no produto, explorando as relações entre tecnologias digitais e capacidades que emergem nesse cenário. Baseando-se em trajetórias de transição relacionadas à oferta de valor e na relação entre tecnologias emergentes e o desenvolvimento de novas capacidades de serviço, os objetivos específicos foram definidos como: (i) caracterizar a evolução da oferta de valor no ciclo de vida da indústria dentro de uma empresa líder em manufatura em seu setor, identificando lançamentos de produtos/serviços e suas motivações; (ii) identificar a relação entre capacidades emergentes e tecnologias digitais para o desenvolvimento futuro da servitização digital e avaliar seu impacto nas estratégias empresariais; e (iii) avaliar como a relação entre tecnologias digitais e capacidades se aplica em uma indústria centrada no produto focada na servitização digital. Espera-se que os resultados desta pesquisa contribuam para o campo da servitização digital, com foco nas tendências mais recentes e nos desafios que emergem da combinação entre servitização e digitalização. Ao integrar essas dimensões, busca-se iluminar tanto as necessidades de empresas quanto de literatura para desenvolver uma compreensão mais profunda das capacidades tecnológicas e organizacionais que podem sustentar a transição digital em indústrias centradas no produto.

## Metodologia

Esta pesquisa foi dividida em três fases principais, cada uma com etapas específicas e procedimentos metodológicos distintos que buscaram responder aos objetivos definidos. Cada fase incluiu uma combinação de revisão bibliográfica, estudo de caso e análise de dados. Na Fase 1, foi realizada uma revisão de literatura para entender o problema de pesquisa, focando nas trajetórias de transição de servitização em indústrias de manufatura. A pesquisa incluiu um estudo exploratório em uma empresa centrada no produto, aplicando conceitos identificados na revisão da literatura. A fase foi dividida em cinco etapas. Primeiramente, foi realizada uma revisão de literatura, que identificou o estado da arte em servitização, permitindo uma compreensão aprofundada das trajetórias e desafios enfrentados por empresas de manufatura. Em seguida, desenvolveu-se um framework baseado no ciclo de vida da indústria e nas diferentes trajetórias de servitização para empresas centradas em produtos, fundamentando-se nos resultados da revisão de literatura. A terceira etapa foi a seleção do estudo de caso, onde escolheu-se uma empresa representativa do setor, com dados documentais e acesso a colaboradores que possibilitassem o desenho preciso de sua trajetória. Na etapa seguinte, documentaram-se os lançamentos e as motivações da empresa em resposta ao mercado. Por fim, as motivações foram analisadas e comparadas com a literatura para identificar novas contribuições e compreender as decisões empresariais. Na Fase 2, foi realizada uma revisão sistemática da literatura em servitização digital, categorizando tecnologias e capacidades emergentes, o que possibilitou o desenvolvimento de um framework conceitual. Primeiramente, identificaram-se os campos onde serviços digitais estão emergindo, categorizando-os em modelos de negócio, sistemas gerenciais e desenvolvimento de sistemas produto-serviço (PSS). Em seguida, foram identificadas as capacidades e tecnologias digitais relevantes com base na categorização dos campos de inovação. Na etapa seguinte, analisaram-se as associações entre capacidades e tecnologias, resultando no desenvolvimento do framework conceitual. Por fim, identificaram-se lacunas e direções futuras na literatura, justificando a necessidade da Fase 3.
A Fase 3 aplicou o framework desenvolvido na Fase 2 em um estudo de caso na indústria automotiva, com foco na estratégia de oferta de valor digital. Um estudo de caso único foi escolhido para uma análise profunda e abrangente, permitindo a validação e o incremento do framework. Na primeira etapa, elaborou-se um protocolo de entrevista com perguntas fechadas e abertas baseadas na revisão de literatura, cuja versão completa encontra-se no Anexo B. Em seguida, confirmaram-se as tecnologias e capacidades digitais mencionadas pelos entrevistados, os dados foram categorizados e analisados quanto às inovações observadas na oferta de valor. Por último, o framework conceitual original foi revisto e aprimorado, resultando no principal produto desta fase. Para a análise de dados, utilizou-se uma abordagem qualitativa e exploratória, com triangulação de dados de documentos internos da empresa e transcrições de entrevistas, utilizando Microsoft Excel para a codificação e identificação de padrões consistentes.

## Resultados e Discussão

Este estudo proporcionou uma compreensão mais profunda das estratégias adotadas e das mudanças motivacionais ao longo da trajetória de servitização. Foram identificadas novas motivações não abordadas anteriormente na literatura, como entrada em novos mercados e exploração de valor tecnológico. Observou-se que, conforme novas tecnologias surgem, a oferta de valor da empresa é impactada, adaptando-se às exigências de um mercado em maturidade por meio de sistemas complexos que combinam produtos e serviços de maneira interdependente. A análise da literatura existente sobre as tecnologias digitais e capacidades emergentes no contexto da servitização digital permitiu a criação de um quadro conceitual preliminar. Este quadro identifica e categoriza as interações entre tecnologias digitais e capacidades, ampliando a compreensão sobre os recursos necessários para a inovação digital e

oferecendo um modelo claro para fabricantes que buscam adotar a servitização digital. O estudo permitiu desenvolver insights práticos para gestores sobre como integrar essas tecnologias e capacidades para promover a inovação em seus negócios. Os resultados do estudo de caso na indústria automotiva forneceu evidências práticas que corroboram as relações identificadas na literatura, além de identificar barreiras enfrentadas pela empresa no processo de servitização digital. Observou-se que a definição e categorização de capacidades específicas são pouco exploradas na literatura atual, sendo frequentemente inferidas como secundárias. Este estudo, portanto, propôs cinco categorias de capacidades com base em exemplos práticos, incluindo a capacidade de integração de tecnologias e a utilização de dados para inovação de serviços. O quadro conceitual desenvolvido esclarece as dinâmicas de relação entre categorias de capacidades e tecnologias digitais, anteriormente tratadas de forma isolada na literatura. Esse quadro facilita a análise e a avaliação do impacto de campos de inovação nos processos de servitização. Empresas podem adaptar suas estratégias e tomar decisões informadas sobre a adoção e integração de novas tecnologias em seus modelos de negócio.

A verificação empírica do quadro conceitual revelou que a servitização digital demanda capacidades organizacionais novas, como a orientação para dados e a integração tecnológica, fundamentais para a transição de modelos focados em produtos para modelos centrados em serviços. Exemplo disso é o papel das capacidades de integração de dados e processos de design de serviços, que são chave para implementar tecnologias emergentes, como IoT e inteligência artificial no valor ofertado. Outras capacidades como a padronização global e a melhoria contínua de processos também emergiram como essenciais para empresas que buscam oferecer experiências de serviço consistentes e de alta qualidade. Além disso, a literatura destaca a importância de combinar múltiplas tecnologias digitais no processo de servitização. Por exemplo, a convergência de IoT, análise de big data e computação em nuvem cria sinergias que impulsionam soluções de serviços inovadoras. Essa abordagem integrada permite que fabricantes ofereçam serviços responsivos e adaptáveis às necessidades dos clientes, gerando valor de maneira ágil e estratégica.

**Conclusões**

Este estudo explora o fenômeno da servitização em um ambiente de manufatura centrado em produtos e caracteriza os caminhos de transição relacionados à oferta de valor e à relação entre tecnologias emergentes e o desenvolvimento de novas capacidades de serviço. Embora a literatura sobre servitização digital esteja em crescimento, as tecnologias digitais emergentes estão em constante mudança, o que demanda suporte para a tomada de decisões por parte dos praticantes, evidenciando a lacuna de pesquisa que este estudo abordou. A pesquisa fornece uma compreensão mais profunda das tipologias de servitização e das motivações das empresas para a transição, assim como um framework conceitual que ajuda as empresas a navegar nas complexidades da integração de modelos orientados para serviços. Os resultados destacam que tecnologias digitais combinadas com capacidades como melhoria de são cruciais para essa transformação. Além disso, a falta de taxonomia e categorização das tecnologias digitais e capacidades foi identificada como uma limitação. A discussão sobre tecnologias digitais frequentemente carece de clareza sobre seu potencial único, sendo essencial ilustrá-las como tecnologias distintas para uma compreensão mais clara e uma integração estratégica adaptada às necessidades específicas.As barreiras à implementação de tecnologias digitais foram identificadas, incluindo a necessidade de proatividade na gestão de grandes volumes de dados em nuvem e problemas de segurança. Os resultados destacam áreas críticas que precisam de melhorias para facilitar a implementação bem-sucedida das tecnologias digitais. Por fim, as limitações do estudo incluem a generalização das conclusões para indústrias com diferentes estruturas e desafios, sendo recomendada uma abordagem quantitativa em pesquisas futuras para robustez dos resultados. A análise de casos cruzados também poderia permitir a

generalização dos resultados e fortalecer as descobertas sobre tecnologias digitais emergentes e capacidades na servitização digital.

**Palavras-chave:** Servitização digital; tecnologias digitais; capacidades.

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## LIST OF ACRONYMS

AI – Artificial intelligence

AR – Augmented reality

B2B – Business to business

B2C – Business to customers

CoSP - Complex product and system

CPS - Cyber-physical systems

EBIT - Earnings before interest and taxes

HUDs - Head-up displays

IT – Information technology

IoT- Internet of things

KPI – Key-performance indicator

MPVs – Multi-purpose vehicles

PPE - Personal protective equipment

PSS – Product-service systems

R&D - Research and development

SSC - Services support a client

SSP - Services supporting their products

SUVs – Sports utility vehicles

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# CHAPTER 1 – INTRODUCTION

Services represent an important offer for manufacturing companies aiming at differentiation and gaining competitive advantage (VISNJIC; VAN LOOVEY, 2012; FAVORETTO et al., 2022). Different motivations such as competitiveness, demand from clients, and economic reasons regarding product complexity (RADDATS et al., 2015; TRONVOLL et al., 2020) have led manufacturing companies to consider offering services through different operations models (BAINES et al., 2020). This process of adding services - known as the servitization of manufacturing - has created additional value for many manufacturing companies worldwide (BAINES et al., 2009; 2020). When embarking on the transition to services, Raddats et al. (2015) stated that manufacturers must change their product-oriented mindset to prioritize services in business strategies. Nevertheless, servitization is traditionally approached in the existing literature as adding services to products to offer a PSS (BAINES et al., 2007). This approach only benefits the literature in service-oriented servitization (KAMAL et al., 2020). In the case of product-oriented servitization, adding intelligence (software), interaction with the environment (actuators and sensors), or connectivity to the product may also result in a PSS (PORTER; HEPPELMANN, 2015). There is broad agreement that digital technologies facilitate the development of service innovations in manufacturing organizations (VILKAS et al., 2021).

In today's rapidly evolving business landscape, the concept of digital servitization has emerged as a transformative force, revolutionizing traditional industries by integrating digital technologies with service offerings. This paradigm shift has enabled companies to move beyond the mere provision of products and embrace a more holistic approach, where value is derived from the combination of physical goods and digital services. As a result, digital servitization has gained significant attention from scholars, practitioners, and policymakers alike, as it holds the potential to enhance customer experiences, drive innovation, and create new revenue streams (LANGLY, 2022).

Digitalization is transforming companies' servitizations (FAVORETTO et al., 2022). The fast pace of digital technologies appearing in parallel to the servitization of manufacturers' journeys institution raises the need to develop new capabilities to be competitive in the market. With the development of "Industry 4.0", the service level has become the standard for measuring the manufacturing capability of a country, and various production support modes have derived from it (CHEN et al., 2022). Recent studies have shown specific cases where a

determined capability was called to be developed within an organization such as product/service development and business model innovation (HALLSTEDT, 2020; WEKING, 2020) in addition to data-related capabilities (SJÖDIN et al., 2021; DALENOGARE et al. 2022; SCHYMANIETZ et al., 2020; HUSSNAIN et al., 2020). This is a phenomenon corresponding to the emergence and development of digital technologies such as AI (SJÖDIN et al. 2021), IOT (CONG, 2022; SALA 2022), and digital platforms (ELORANTA; ARDOLINO; SACCANI, 2021). The introduction of new digital technologies will stimulate Product-service systems evolution and researchers to rethink the existing research concerning both business models and management, engineering, and design. Among them are the changes in the design tools, the business model, and the organization, operations, and standards (GAIARDELLI, 2021). In addition, in their efforts to capitalize on digitalization, companies may rush to commercialize new digital business models without carefully considering the consequences (LINDE, 2020).

There is a gap in the literature that points out the need to understand digital servitization and its relation with digital technology trends as highlighted by Paschou et al. (2020) systematic literature review. The scope of the investigation should be enlarged regarding the technologies covered and their combinatory effect, the potential benefits, and the application domains and to develop models and frameworks to support decision-making by practitioners (PASCHOU et al., 2020). According to Favoretto et al. (2022), recent studies make it clear the convergence between the phenomenon of digitalization and servitization but still lack clarification in this relationship. Some of the results of the research show new literature questions such as “what typologies of PSS result from the value proposal focused on services, information, and technologies?” (FRANK et al., 2019; PIROLA et al., 2020; ZHENG et al., 2019) and towards more specifically the capabilities in this context such as “what are the combinations of resources and capabilities that can lead to the success of digital servitization? How can the capabilities related to digital platforms bring competitive returns to companies? (ARDOLINO et al., 2018; COREYNEN et al., 2020; DE LA CALLE et al., 2020; HSUAN et al., 2021; PAIOLA; GEBAUER, 2020). Based on the identified gaps and the need for further research outlined, the research opportunity can be formulated with the question: what combinations of digital technologies and capabilities are critical for the journey of digital servitization in a product-centric manufacturer?

## 1.1.OBJECTIVES

The main objective of this thesis is to characterize the phenomenon of digital servitization in a product-centered manufacturing environment, underlying the relationships between digital technologies and capabilities that emerge in this context. It is based on the transition paths related to the value offer, and the relationship between emerging technologies and the development of new service capabilities. The specific objectives were defined as follows:

a) OB1: Characterize the value offer evolution in an industry life cycle within a manufacturing company leader in its industry sector, with the identification of product/services launches and their motivations;

b) OB2: Identify the relationship between emerging capabilities and digital technologies for future development of digital servitization and evaluate its impact on companies' strategies;

c) OB3: Evaluate how the relationship between digital technologies and capabilities applies in a product-centered industry focused on digital servitization.

This research contributes to the field of digital servitization latest trends, such as the study of when organizations use digital technologies in the processes and offerings related to servitization, the combination of servitization and digitalization raises new challenges that should be addressed in future research (MORAES; CUNHA, 2022). The study brings light to need of identification of, both, literature and company perspective, the needs in terms of technology and capabilities involving product-centered industries dynamics transition (WEKING et al., 2020; TIAN et al., 2022; PIROLA, et al. 2020; SCHYMANIETZ et al., 2022).

## 1.2. RESEARCH RELEVANCE

As a first motivator for this research is the literature presenting that companies frequently adjust technologies and processes to challenge conventional offers (BAINES, 2019). While being approached as innovation in business models, sometimes during servitization, the value proposition of manufacturing companies can be the same, only changing how it is defined, designed, and delivered (PAWA et al., 2009). This means that the same value proposition may be operationalized by different products and services or a combination thereof and it should be further explored.

Secondly, servitization trajectories in the existing literature have been presented as unidirectional and service-targeted paths (TUKKER, 2004; KOWALKOWSKI et al., 2015). Nevertheless, it is also necessary to evaluate different trajectories that a manufacturing company may choose while evolving through different product-service systems (KOWALKOWSKI et al., 2017). Smart connected products are an example of how the addition of sensors, actuators, software, and connectivity to products can provide services to customers and improve competitive advantage for manufacturing companies (PORTER; HEPPELMANN, 2014). Thus, the compelling offerings might be not only services but also the development of products that sell services and differ from competitors (AUGUSTE et al., 2006). The results of the research conducted by Favoretto et al. (2022) suggest that it is still necessary to understand the transition to services of manufacturing companies, the trajectory of the company's business model innovation, and the enablers that drive manufacturers through the value offer and provision of such services. Since then, many studies looking at servitization trajectories have emerged (BAINES et al., 2020; FAVORETTO et al., 2022). It is also well-known that the differences in the industry phases demand different types of services (CUSUMANO et al., 2015). Therefore, previous authors add that it is important to identify other important factors that affect servitization pathways.

Lastly, there are recent literature review papers that present digitalization and its technologies as enablers to develop and improve the capabilities for servitization in manufacturers (ZHENG et al., 2021; PASCHOU et al., 2020; PIROLA, et al. 2020). The focus is to show the benefits and barriers that companies face, but it lacks the vision of which capabilities at different levels are connected with which digital technologies are created. Some recent studies are calling for new research to focus on the study of new and evolved capabilities necessary to develop the increasingly complex products and solutions and a more detailed understanding of the needed capabilities, and practices are needed (HALLSTEDT et al., 2020; KOHTAMÄKI et al., 2020).

Therefore, this research will contribute to recent literature of digital servitization, addressing the calls for answering the questions of how digital technologies and capabilities relate to each other in the field of digital servitization and how it affects the servitization path of manufacturing firms during its lifecycle.

## 1.3.RESEARCH STRUCTURE

This thesis is presented in the format of a paper collection, which means that it is based on a series of 3 papers. It is divided into 6 chapters. The current chapter (Introduction) explains the context of the research with its objectives and relevance, followed by Chapter 2 which describes the research methods applied for the thesis and the phases of the research correlating the output of each phase and the input in the next phase, and how it was constructed. Phase 1 is the research problem understanding, while phase 2 consists of a literature review and conceptual proposal development, and finally, phase 3 applies the conceptual proposal in an empirical case-based approach.

As stated in Table 1.1, Chapter 3 consists of a literature review of servitization transition paths of product-centered companies and a manufacturing study case of servitization towards its industry life cycle, in which a market leader company was evaluated in terms of products and services launches in each servitization transition path that the company decided to pursue. The motivations were identified and the results were compared to current literature. The chapter provided an understanding of the research problem as part of phase 1 and resulted in the first paper. In Chapter 4, there is a systematic literature review of the emerging capabilities and technologies in the context of digital servitization, with the development of a conceptual framework that illustrates the relationship between technologies, capabilities, and fields of innovation identified in the recent research. In Chapter 5, a new study case was conducted in a different industry that presents an innovative and recent digital servitization strategy developed, in the automotive industry of a multinational conglomerate. This chapter presents the innovations in the value offer reflected on new services and PSS's, based on developing and implementing the digital technologies and capabilities previously shown in the literature. The last chapter, 6, consists of the research conclusions, suggestions for continuation on future research and limitations faced.

Table 1.1: Relation between objectives and each paper according to its respective chapter.

(continues)

| Objectives | Research method | Main results | Chapter | Paper | Journal / Conference – Submitted (S) or Published (P) |
|---|---|---|---|---|---|
| To identify and analyze alternative product-oriented servitization trajectories. Specific objectives are (i) a timeline drawing of the evolution of offers considering the industry life cycle context; (ii) detecting milestones of any product or service launches; (iii) identifying motivations that led the company through the changes identified; and (iv) finding patterns through the correlation between motivations and company response. | A longitudinal case study is divided into (i) data collection through semi-structured interviews and complemented by secondary sources, and (ii) a content analysis with a framework based on literature. | The timeline framework with the industry life cycle was configured with twenty products and services launches identified, correlated with ten motivations, presenting three new servitization paths. The principal pattern identified was the tendency in the last phase of the industry lifecycle, in which more servitization paths were related to systems rather than complex products. New motivations emerged when compared with already studied trajectories in the existing literature, such as (i) entry into a new market, (ii) technological advancement, and (iii) value exploitation. Seven other motivations occurred, converging with previous research. | Chapter 3: Manufacturing study case for servitization towards industry life cycle | The trajectory of Product-Centric Servitization: Contributions from a Case Study in a Complex-Product Provider | ENEGEP 2023 (P) – preliminary version in Portuguese. Benchmarking: an international Journal (S). |

Table 1.1: Relation between objectives and each paper according to its respective chapter.

(continuation)

| Objectives | Research method | Main results | Chapter | Paper | Journal / Conference – Submitted (S) or Published (P) |
|---|---|---|---|---|---|
| To identify and summarize the patterns in recent literature in the field of digital servitization, with a focus on evaluating emerging capabilities and digital technologies. Specific objectives are (i) systematic literature review; (ii) analysis of recent research; (iii) identification of emerging capabilities and digital technologies and (iv) direction patterns and new call for research for future development of digital servitization. | The systematic literature review was organized and divided into the phases of (i) search query, (ii) data sourcing, (iii) screening, (iv) use of analytic tools, and (v) content analysis - affinity diagrams used and framework developed. | Within the fields of innovation in business models, PSS development, and managerial systems, a total of 5 different categories of capabilities and 6 categories of technologies were exemplified with the applicability examples. A framework was developed, which evidences the relation observed between the different capabilities and technologies in which organizations are being strengthened and improved. | Chapter 4: Capabilities and technologies in digital servitization – a conceptual framework | Digital servitization and its forthcoming trends covering emerging capabilities and digital technologies in manufacturers: a systematic literature review | ENEGEP 2024 (S) – preliminary version in Portuguese. Production Journal (S). |

Table 1.1: Relation between objectives and each paper according to its respective chapter.

(continued)

| Objectives | Research method | Main results | Chapter | Paper | Journal / Conference – Submitted (S) or Published (P) |
|---|---|---|---|---|---|
| Evaluate how the relationship between digital technologies and capabilities applies in a product-centered industry focused on digital servitization. | Case study consistent of (i) interview protocol based on a previously conceptual framework designed to support, (ii) semi-structured interviews conducted, (iii) content analysis. | Conceptual framework was improved by a new innovation field, operation. Two digital technologies were identified, machine learning and artificial neural networks. Three new capabilities were also categorized. Barriers on digital servitization journey were identified such as proactiveness and accuracy on use of big data, security concerns on usage of cloud, legacy of old systems, cultural change, prioritization of investments and knowledge sharing. | Chapter 5: Digital servitization in automotive industry | Digital servitization and its value offer strategy: a case study in the automotive industry. | Not applicable |

# CHAPTER 2 - RESEARCH METHOD

This chapter describes the research method and the phases of this research in detail. It is presented the correlation between objectives, the respective steps taken in each phase to achieve the objectives, and its respective outcomes. As illustrated in Figure 2.1, phase 1 was dedicated to understanding the research problem by a literature review of transition paths in the servitization of manufacturing industries literature. It was also performed an exploratory study on a product-centered manufacturer applying the concepts found in the literature review. Phase 1, which resulted in Chapter 3 and paper intitled "The trajectory of Product-Centric Servitization: Contributions from a Case Study in a Complex-Product Provider", was divided into five main steps. In the first step, the literature review was performed and allowed the researcher to understand the state-of-the-art in the field of servitization. The second step was dedicated to elaborating a framework based on the industry life-cycle and different servitization trajectory paths for product-centered firms. The basis for this was the results of step 1, providing the researcher with the literature based correlation between the servitization paths found in the field and the concept of the industry life cycle. As a third step, there was the selection of a case study that would be representative of its industry and provide enough documental data and access to its employees to have an accurate design of its trajectory. The case study selection and data collection are explained on Chapter 3. The fourth step consisted of the identification of product/service releases and the company's motivations for its responses to the market. In the last step, these motivations were analyzed and compared to the literature, also to find new contributions and explanations for the decisions made.

Phase 2, which resulted in Chapter 4 and paper intitled " Digital servitization and its forthcoming trends covering emerging capabilities and digital technologies in manufacturers: a systematic literature review", focused on a systematic literature review in the field of digital servitization, categorizing the emerging technologies and capabilities, and allowing the author to observe correlations stated between the two and develop a conceptual framework. To do so, the phase was divided into 4 main steps. First, step 1 identified the innovation fields where digital services are emerging and categorized them into three groups: business models, managerial systems, and PSS development. Followed by step 2 which identifies the emerging capabilities and digital technologies presented in those fields. With the capabilities and technologies identified, step 3 allowed an analysis of the association between the capabilities and technologies resulting in a conceptual framework. The last step of this phase identified and

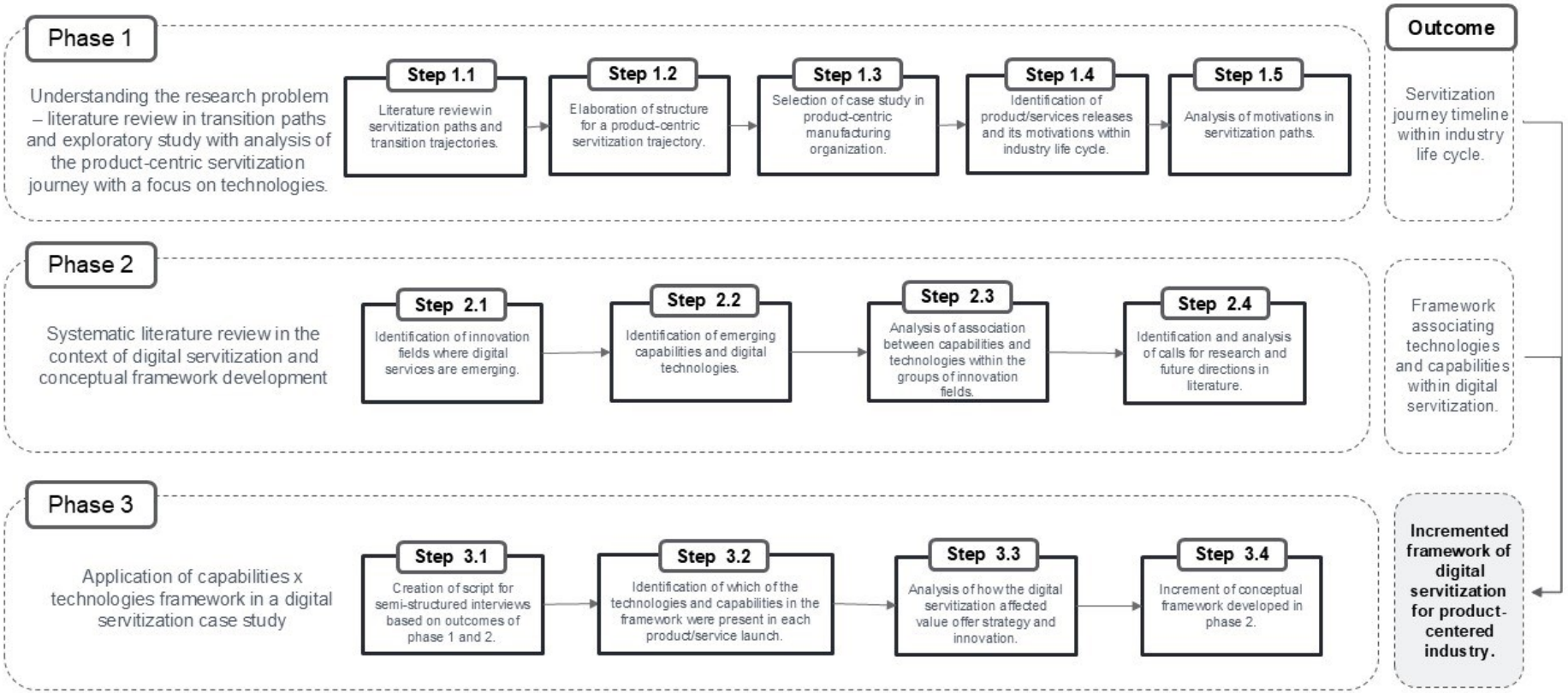
analyzed the calls for research and future directions in literature, to verify the relevance of phase 3 in this research. . The data base, method of search and data analysis are explained on Chapter 3.

Finally, phase 3, which resulted in Chapter 5 and paper intitled “Digital servitization and its value offer strategy: a case study in the automotive industry”, consists on the application of capabilities and digital technologies conceptual framework developed in the preceding chapter, in the product-centered automotive industry and its value offer strategy. One case study is explored, allowing the researcher to validate and increment the framework. A unique case-study was chosen to support an in-depth and comprehensive analysis. By thoroughly examining a single case study, it is possible to gain deep understanding of a specific context, allowing a more nuanced interpretation of the results (YIN, 2009). The company selected presents a digital servitization strategy in place, and its value offer covers entire automotive supply chain. The choice was made on the criteria of this company being a product-centric manufacturer, being inserted in a context of mature industry and having shown constant digital innovations in its value offer. In addition, it provided the researcher the opportunity to explore data longitudinally, that is, at different moments, and there was unlimited access to data[1]. The first step of the study was the interview protocol creation with a mix of closed-answer questions based on the literature review performed in earlier stages of the research (multiple-choice questions) and open-answer questions. The basis for these questions are recent literature and better explained and referenced in Chapter 5. The full interview protocol can be read in Annex B. Six employees were interviewed from different departments of the company, that way, it allowed a cross-functional perspective on the reality of the company. The departments chosen and the full profiling of informants are detailed in Figure 5.2. In the sequence, step 2 was the confirmation and/or identification of digital technologies and capabilities presented by interviewees. The third step consisted of data categorization and analysis in terms of innovations in the value offer observed in the case study.

[1]The study case selected has been followed by the researcher since graduation research, and has been open to data access allowing the researcher to interview people and consult documents available for employees under data protection governance agreement.

The data analysis consisted of an iterative process of data collection and analysis, pattern recognition and data triangulation (EISENHARDT, 1989). On the content analysis, the steps included identifying which technologies and capabilities were present in the value offerings, utilizing a coding scheme based on a theoretical framework. Transcripts and company documents were coded using Microsoft Excel, with new codes like barriers and enablers emerging from the data. Pattern recognition identified consistent relationships and themes, aiding in theoretical development. A qualitative and exploratory approach was used to interpret the results, supported by triangulation of data from various company documents (detailed information is given on Chapter 5). The original conceptual framework was subsequently reviewed and improved. The fourth and final step was the increment of the conceptual framework developed in phase 2 of this research, presented as the final outcome and main result.

Figure 2.1: Phases and steps for the research method applied and outcomes of each phase.



To summarize, Table 2.1 shows the relationship between the specific objectives (OB1, OB2, and OB3), each phase, and steps, and it is associated with the method of the papers that resulted from the process. In Chapters 3, 4, and 5, the specific paper research method will be described in depth.

Table 2.1: Specific objectives and their relation with phases, steps, and method approach.

| Specific objectives | Phase | Steps | Method approach |
|---|---|---|---|
| OB1: Characterize the value offer evolution in an industry life cycle within a manufacturing company leader in its industry sector, with the identification of product/services launches and their motivations. | Phase 1 - Research problem understanding | Steps 1.1, 1.2, 1.3, 1.4, 1.5 | Literature review, data collection through semi-structured interviews, and content analysis |
| OB2: Identify the relationship between emerging capabilities and digital technologies for future development of digital servitization and evaluate its impact on companies' strategies. | Phase 2 - Literature review and conceptual proposal development | Steps 2.1, 2.2, 2.3, 2.4 | Systematic literature review; content analysis and affinity diagrams |
| OB3: Evaluate how the relationship between digital technologies and capabilities applies in a product-centered industry focused on digital servitization. | Phase 3 - Empirical case-based approach | Steps 3.1, 3.2, 3.3, 3.4 | Data collection through semi-structured interviews and content analysis |

Phase 1 contributed to OB1 which aims to characterize the value offer evolution in an industry life cycle within a manufacturing company leader in its industry sector, with the identification of product/services launches and their motivations and it provides the outcome necessary to the realization of the need to deep dive into the digital servitization literature. Phase 2 addresses OB2 and focuses on the identification of patterns in recent literature in the field of digital servitization, with a focus on evaluating the emerging capabilities and digital technologies for the future development of digital servitization The last phase should address

OB3, which Evaluate how the relationship between digital technologies and capabilities applies in a product-centered industry focused on digital servitization, to test the conceptual framework and identify possible new relationships not previously explored in literature.

# CHAPTER 3 - TRAJECTORY OF PRODUCT-CENTRIC SERVITIZATION: CONTRIBUTIONS FROM A CASE STUDY IN A COMPLEX-PRODUCT PROVIDER

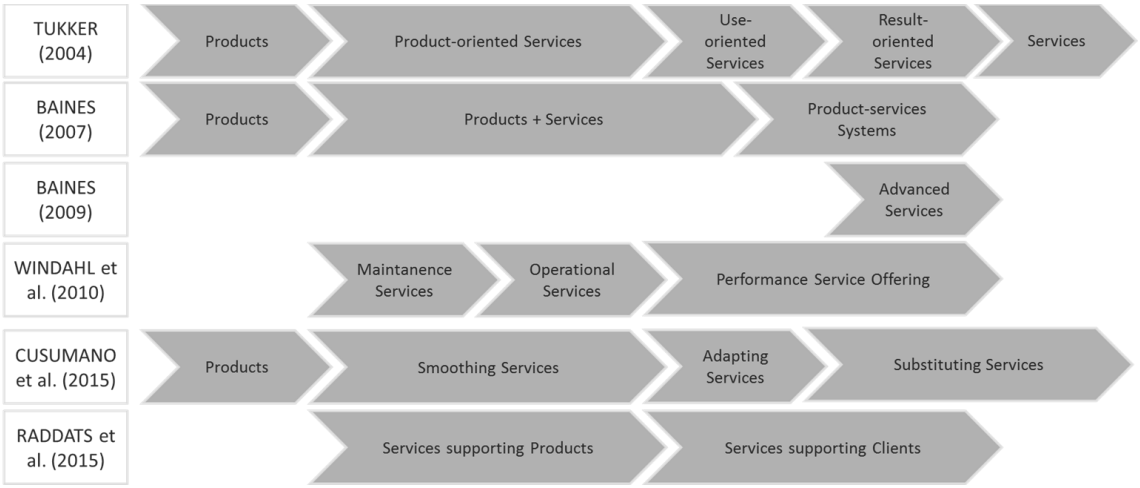
This chapter presents the results of phase 1 and it contains the first paper of the research in which the servitization paths in literature and further one on the exploratory study were identified and provided insights on the dependence on external motivations and company resources in deciding on the servitization orientation and trajectory of manufacturing companies. By identifying new servitization paths, the paper also contributes to the existing literature on the servitization transition process by revealing other patterns not previously identified in empirical studies. Sections 3.1, 3.2, and 3.3 outline a brief theoretical background on servitization pathways, which provides the theoretical basis of the study. Section 3.4 describes the research procedures for data collection and analysis, the case study selection, and the context. Section 3.5 presents the study outcomes in addition to its theoretical and managerial implications. Finally, section 3.6 draws concluding remarks and directions for further work.

## 3.1.SERVICE OFFERINGS IN MANUFACTURING FIRMS

Manufacturing companies have started to offer ‘solutions’ through new business models. Services and support engineering capabilities are centered around enabling productive relationships instead of merely transactions (FAVORETTO et al., 2022; TRONVOLL et al., 2020). The focus is not on the suppliers but rather on all stakeholders as network partners. Baines et al. (2007) pointed out that this concept reflects the evolution of tangible products as being transferred to an inseparable service system integrated within a company. In this context, the concept of PSS) arises. A PSS involves “product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment” (BAINES et al., 2007). A PSS may be viewed as a new operation approach to aggregate functionality to a value proposition in a business model in a way that incorporates additional services to a product (BAINES et al., 2007). There is a change in meaning from the sales point of view, now based not only on the selling of the products but also their use. A PSS may be defined as “tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific customer needs” (TISCHNER et al., 2002). The integration of additional services to the traditional product sales could be first considered as after-sales

services, e.g., repair, reuse, maintenance, and recycling, or even training or consulting (BAINES et al., 2007). Many classifications of services have emerged. Figure 3.1 summarizes some of them that have been discussed in the existing literature.

Figure 3.1: Types of services according to different authors.




Tukker (2004) classified PSS into eight different types according to the main categories of service arrangements. The first one is ‘product-oriented services, in which a company has its major sales revenues from products, and some services are added to complement the products. The other main category is ‘use-oriented services’ when the revenue does not stem from selling the product itself as it remains in the ownership of the provider after the transactions. The product is made available to the user and can, sometimes, be shared with multiple users. The last main category proposed by Tukker (2004) is ‘result-oriented services’, which are characterized by an agreement between the consumer and the company to achieve a given result.

Baines et al. (2009) criticized Tukker’s framework claiming that it tends to focus on the features and examples of the offering rather than on the intrinsic value involved (cost, quality, time). Hence, according to the authors, it is of “limited value to an organization seeking to configure their wider production and support service operations”. Other taxonomies comparable to Tukker’s are commonly suggested in the literature. For example, Raddats et al. (2015) and Mathieu (2001) addressed similar offerings with different nomenclatures such as ‘services supporting their products (SSP)’, whereby the direct recipients of the services are the products, and the services support a client’s actions relative to the supplied products (SSC) and solutions, which are longitudinal relational processes designed to solve strategic customer-specific problems (STORBACKA, 2011). Similarly, Kowalkowski et al. (2016) illustrated

service types such as after-sales, value-added, product-supporting, and customer-supporting services.

Cusumano et al. (2015) proposed three basic services that might be created by a company during its industrial life cycle: smoothing, adapting, and substituting services. Smoothing services do not alter the product functionality and promote a standard transaction between the company and the client. In turn, adapting services impact product functionality since they develop new uses or adaptions for the product. Substituting services are considered more innovative and replace the product, turning it into a complementary share of the offer. Other definitions related to the transition to services are connected with the advancement of new technologies, when the offer is based on the availability of software and data, allowing new trajectory possibilities (TSVETKOVA et al., 2021; KOHTAMÄKI et al., 2021).

## 3.2.PRODUCT-CENTRIC SERVITIZATION STRATEGY

The service strategy determines how the manufacturer competes with services in a given market to achieve differentiation (RADDATS; Kowalkowski, 2014; FAVORETTO et al., 2022). Cusumano et al. (2015) identified three main phases of the industry life cycle and listed different company motivations and reactions regarding the environment and external factors to be considered in the development of the servitization strategies. The “ferment” phase of the industry life cycle is characterized by a high level of uncertainty. Output volumes are low and companies focus on product innovation. During this phase, product companies and customers have not yet accumulated significant knowledge about products, their performance characteristics, or usage patterns. The transition period is characterized by decreasing uncertainty and product cost, given that there are increasingly standardized products with progressively better-understood usages. The mature phase experiences low product and market uncertainty levels and increased cost-based competition.

In this context, smart products are gaining momentum, especially in the mature phase of the industry life cycle, and they are closely related to the concept of a ‘product-as-a-service business’ (PIROLA et al., 2020; ARDOLINO et al., 2018). According to Porter et al. (2015), the product design needs to incorporate additional instrumentation, data collection capability, and diagnostic software features that monitor product condition and performance and can warn the service provider in case of failure. As software increases functionality, products can be designed to allow more remote service. Products delivered as services should also capture usage

data to charge customers appropriately (PIROLA et al., 2020). This requires clear thinking about the type and location of sensors, what data will be gathered, and how often it should be analyzed.

Essentially, Porter et al. (2015) designed the following types of service strategies that may be considered product-centric servitization:

*One-stop service strategy*: because technicians can diagnose problems remotely, they can have the parts needed for repairs in their trucks the first time they arrive at a customer's location and have supporting information to execute the repairs; only one visit is necessary, and success rates rise. *Remote service strategy*: smart, connected products make delivering service via connectivity increasingly feasible; in many cases, products can be repaired by remote technicians the same way that computers are now often fixed, and, as a result, service costs and equipment downtime decrease and customer satisfaction improve dramatically.

*Preventive service*: using predictive analytics, organizations can anticipate problems in smart, connected products and take action; a company can also update a machine with preventive fixes when feature enhancements are added, sometimes remotely.

Aug*mented-reality-supported service strategy*: with information about a product's service needs and step-by-step repair instructions, service efficiency and effectiveness may increase dramatically.

*New services*: the data, connectivity, and analytics available through smart, connected products are expanding the traditional role of the service function and creating new offerings; indeed, the service organization has become a major source of business innovation in manufacturing, driving increased revenue and profit through new value-added services such as extended warranties and comparative benchmarking across a customer's equipment, fleet, or industry.

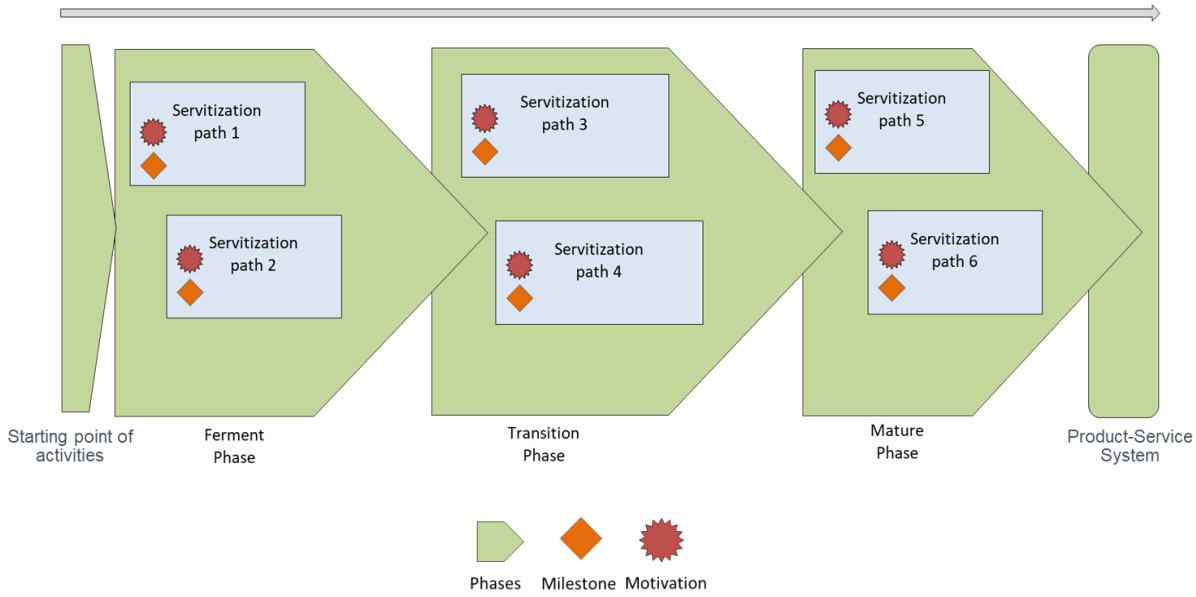
On the other hand, the service strategy may be related to providing solutions with a value co-creation that requires the successful combination of resources from the organization and customer into a valuable solution (VARGO; LUSCH, 2004). For example, while the provider offers capital goods such as machinery and technology, the customer needs to apply its resources, which could be employees or, in the case of an elevator company, the know-how, for example. The more complex and extensive an offering is, the more knowledge components are required. By breaking the component down into products and services and further into associated knowledge components, the integrated solution may be interpreted as a bundle of knowledge components. The bundle includes different types of knowledge, including

knowledge embodied in physical products, intangible yet codified knowledge such as software in information systems, and tacit knowledge such as the know-how of service experts (VALTAKOSKI, 2017; MORO et al., 2019).

## 3.3.FRAMEWORK FOR A PRODUCT-CENTRIC SERVITIZATION TRAJECTORY

Cusumano et al. (2015) highlighted that it is necessary to explore the characteristics and differences in the industry phases and the relationship with certain kinds of services over others and identify key factors that help explain changes and differences in services. A framework in Figure 3.2 was thus designed to establish the general constructs or categories and relationships to be studied in exploring the servitization trajectory through the industry life cycle phases (CUSUMANO et al., 2015). In each phase, it is proposed that product and service launches are milestones that illustrate a servitization path within a company's current strategy.

Figure 3.2: Conceptual framework: servitization trajectory through the industry life cycle with milestones and motivations identified for each servitization path.




The framework contemplates possible motivations related to the product-centric servitization strategy that might result from the industry's life cycle phase characteristics or transition; thus, these motivations may lead to the servitization path identified. The relationships will be well-defined once milestones and motivations are identified and compared with existing literature.

Cusumano et al. (2015) highlighted some possible motivations including: (i) product companies invest in services to diversify their revenue and profit streams when entering the mature phase of the industry evolution; (ii) product companies might offer services under different competitive circumstances and not only as a response to industry maturity or product commoditization; (iii) uncertainty may be so high during the early phase of an industry that services emerge as substitutes for products.

Raddats and Kowalkowski (2014) also indicated that a manufacturer is held by its customers, so its motivations may be based on several intangible issues that may positively impact the success of its services. Additionally, knowledge-based capabilities, processes, and organizational structures might interfere with the movement of an organization towards servitization paths. This work intends to ascertain if those patterns appear and which new motivations a product-centric servitization might show.

## 3.4.RESEARCH METHOD

As the goal of this research is to explore product-centric servitization trajectories, case-based research was employed to explore and understand the phenomenon within its context (VOSS et al., 2002). An in-depth analysis of a case of a company that embarked on a product-centric servitization pathway was conducted to understand the details of the process, as described next.

### 3.4.1.Case study selection

A multinational manufacturing company that provides solutions for vertical mobility was selected for analysis. The company is product-centric, which means that its mission is to provide vertical displacement with products bearing their seal. There is no intention to outsource the manufacturing activities as those consist of the company's core business. Nevertheless, the company and the market in which it operates have a background of service needs, and this organization has then considered service infusion into its product offers. Thus, it represents a relevant case of a product-centric company following a servitization process.

The culture of the company's collaborators has already demonstrated a focus on differentiation. In addition, this organization operate in both business-to-business context, i.e. sales are made to the government (through bidding), construction companies, commercial buildings, and business-to-customer contexts, in which transactions occur directly with end users, such as residential customers. The company's main products are elevators, fingers,

footbridges, electronic and mechanic bridges, moving staircases, and conveyors. The actual services provided are divided into installation, repair, maintenance, and modernization. Services merged with the product are more recent and will be discussed later on but can be summarized as connectivity and machine intelligence. The existing market in which the company operates (Latin America) is a solid and well-established market, composed of traditional and large companies.

The company subsidiary in an emerging economy is one of the largest lifting solutions manufacturers. The Brazilian industrial park employs around 4,000 workers. The factory serves the national market and exports to other Latin American countries. More than 60 branches and service stations are located in different regions of the country, ensuring national coverage. Due to the requirement of a complex manufacturing structure, the production is restricted to a few multinational groups, and the Brazilian factory was considered for analysis due to its relevance. The company is one of the three world leaders in the market and retains more than 10% of the market share. When this research was conducted, the provided services were responsible for 60% of the company's revenue. This figure is relatively common in this sector due to maintenance services, which can also be offered to customers who have bought their products from another producer, i.e., the company also offers only maintenance services. In other words, services are a strategic way for the company to retain old customers or capture new ones. Given the potential for the company to undergo a product-centric servitization strategy, it was selected as a relevant case to fully explore the process and possible trajectories.

### 3.4.2.Data collection and analysis

The data collection involved both primary and secondary sources. Longitudinal data was collected through a documentary and historical data-gathering process. The framework that provided the phases of the industry life cycle (Figure 3.3) was considered to design semi-structured interviews. The interviews were conducted with seven employees from a multidisciplinary team from different departments including the service management, marketing, logistics, innovation, and research and development (R&D) departments (Table 3.1). Interviewees from different departments were selected as those who could provide information from a range of different perspectives, highlighting different aspects of the transition process. The interviews lasted one hour each and the framework was introduced to the interviewees, along with the main concepts involved.

Table 3.1: Informants profile.

| Functional area | Position | Years in the company |
|---|---|---|
| Marketing | National Manager | 10 |
| Services management | Junior Analyst | 6 |
| Services management | Senior Analyst | 32 |
| Logistics | National Manager | 28 |
| Innovation | Director | 20 |
| Shared Services Center (SSC) | Senior Analyst | 21 |
| Research and Development (R&D) | National Manager | 15 |

The purpose of adopting the framework as a guide during the interviews was to identify the service growth trajectory of the company, recognize products and service launches, the motivations that led the company to follow the paths, and management plans that supported the transition stages. Additional questions were related to the main difficulties faced by the company, the strategy developed and how the company changed its past strategy on standardization or customization based on the literature (e.g., BAINES et al., 2008; KOWALKOWSKI et al., 2015), the key drivers and general enablers in the transition towards a more servitized company, and how the implementation took place. The interviews were recorded and transcribed afterward. The interview data was also triangulated with other data sources including intranet portal information, catalogs, formal launch documents, the company's internal portfolio, key performance indicators, formal reports to managers, and marketing data. The data was analyzed and coded using QSR NVivo 10 software.

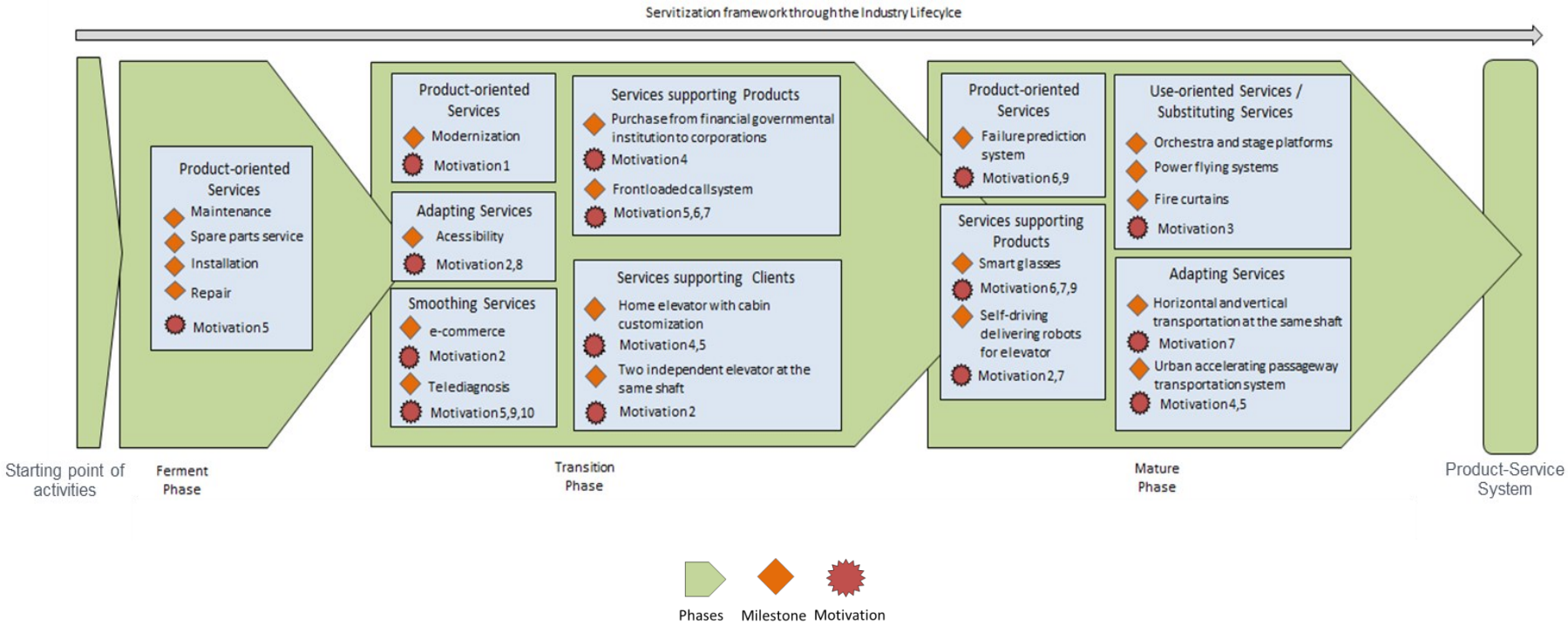
The data was coded by considering the predefined categories of interest as described in the framework. In total, 18 total codification codes were identified. All data from the interviews and documents were coded according to servitization paths identified in each industry life cycle phase, with a total of eight codes. Eight more codes for motivation categories branch from these initial codes. Lastly, two more codes represented barriers to servitization and enablers/strategies adopted by the company in this process. The classifications regarding the framework previously presented were organized in a timeline logic, as interviewees identified the milestones and motivations over each phase. The milestones can be identified as being the launch of any product or service. The framework's constructs also included the identified servitization type (TUKKER, 2004; BAINES, 2007; BAINES, 2009; WINDHAL, 2010; RADDATS et al., 2015). The data were then compared with previous research to plot any behaviors differing from those already known in the literature.

## 3.5. RESULTS AND DISCUSSION

Figure 3.3 summarizes the results according to the proposed conceptual framework. In total, 20 milestones were identified by the interviewees. Every product launch intrinsically has some service related to the company's competencies. For example, a new product may predict a similar maintenance competence but still implies a new maintenance pattern due to the new technical specifications of the product. As mentioned previously, each milestone was pointed out in its respective industry life cycle phase during the interview, and every classification was supported by historical data provided by the company's marketing team.

The last two phases presented the highest number of launches, with eight each (either a new product, new service, or improvements to a product/service already in the portfolio). Some servitization paths do not follow Cusumano et al.'s (2015) suggestions: substituting services did not occur in the ferment phase but was mentioned in the last one, the mature phase. Nevertheless, the results converge regarding smoothing services, exclusive to the transition phase. The divergences may be justified by a variable not considered by Cusumano et al. (2015), such as the classification of complex products and systems - CoPS (REN; YEO, 2006; RADDATS et al., 2015). CoPS encompass customization of the product or respective system and differs from non-complex products because of their high level of added value. Ren and Yeo (2006) suggested that the CoPS classification may be subdivided into complex products and systems, with complex products being standalone entities and systems being complex products that are fully integrated into a system. The primary distinction between them is that the first does not need a system to work properly. The relationships among the motivation, the servitization path adopted by the company, and the product category are discussed later on.

Figure 3.3: Conceptual framework: Servitization trajectory through the industry life cycle with milestones and motivations identified for each servitization path.



It is important to emphasize that many of these milestones in Figure 3.2 were related to two or more motivations that led the company through the classified servitization path. In addition, some motivations mentioned by the company's employees had already been referenced in the literature, with the addition of three new findings: new market entrance, technological advancement, and value exploitation. There is a consideration to be made regarding the latter since the company responds differently to this same motivation. On the one hand, the company looks at the need to improve the product to facilitate service provision. On the other hand, it prioritizes the need to improve the service to improve product performance. Table 3.2 details motivations that emerged during the data collection and illustrates convergences with the literature and the new findings. It can be observed that motivations change along the servitization journey in a sense that they turn from defensive to offensive, demonstrating the company's maturity and capability of assuming new paths. As the results illustrate, the findings were claimed by different interviewees from different departments within the company.

Table 3.2: Motivations identified throughout the servitization trajectory compared to previous research.

(continues)

| Motivation | Description | Previous research | Interviewees | Phases |
|---|---|---|---|---|
| 1 | Diversify their revenue | Cusumano et al. (2015) | Senior. services analyst | Transition |
| 2 | Respond to different competitive circumstances | Cusumano et al. (2015) | National R&D manager, Innovation director, National logistics manager | Transition, Mature |
| 3 | Emerge substitutes for products | Cusumano et al. (2015) | National marketing manager | Mature |
| 4 | Expand demand for products to diversify the client segments | Raddats and Kowalkowski (2014) | National marketing manager, Sr. services analyst, National R&D manager | Transition, Mature |
| 5 | Customer retention | Baines (2015) Martinez et al. (2018) | Innovation director, National R&D, Sr. services analyst | Ferment, Transition, Mature |
| 6 | Influence of competitors | Cusumano et al. (2015) | National R&D manager, Innovation director, National marketing manager | Transition, Mature |
| 7 | Search for differentiation | Ulaga & Reinartz (2011) | Senior. SSC analyst, Innovation director, National logistics manager | Transition, Mature |

Table 3.2: Motivations identified throughout the servitization trajectory compared to previous research.

(continued)

| Motivation | Description | Previous research | Interviewees | Phases |
|---|---|---|---|---|
| 8 | New market entrance | Not found in the literature | National R&D manager | Transition |
| 9 | Technological advancement | Not found in the literature | Innovation director | Transition, Mature |
| 10 | Value exploitation | Not found in the literature | Inferred | Transition |

### 3.5.1.Servitization paths in the ferment phase

In this phase, the first services emerged right at the beginning of the company activities, together with the product launches, accompanying their sales. All four milestones identified in this phase were classified as product-oriented services (Tukker, 2004), given that products played a key role in the company's revenue, while services were complementary. Maintenance, spare parts provision, installation, and repair are the most traditional services in this market, and, according to the senior SSC analyst:

> *'Nowadays, these services are the flagship of the company. Yet, some projects aim to increase revenue from other service types. The representativeness depends on the moment because the market fluctuates'.*

The company's KPI reports indicate that 70% of revenue stems from maintenance services, followed by installation, repair, and spare parts services. Here, the motivation reported was not found in the literature: that service launches allowed for improving product performance. As observed by the senior services analyst:

> *'Every elevator sale, for example, can include a service contract. This way, we can retain this client with a long-term relationship. Besides that, the equipment's warranty is bound by maintenance continuity with our company.*

### 3.5.2.Servitization paths in the transition phase

In this phase, servitization paths were more diversified, with five types identified. It is worth highlighting that, in this phase, returns over investments are more stable, and product costs are predictable. In addition, customers are more comfortable with the company's offer proposals (ABERNATHY; UTTERBACK, 1978; CUSUMANO et al., 2015). Still, regarding

product-oriented services, modernization services arose, explained by the innovation director as follows:

> *'Property owners increasingly need to invest in modernizing their people's transportation systems. We work with customers worldwide to prolong their systems' lifespans safely, intelligently, and cost-effectively.*

Modernization services may be useful for the aesthetic improvement of a product or a change in technological components. It is a formal service not directly related to the product. The motivation was to diversify the revenue, as stated by the senior services analyst:

> *'Our company added the modernization service as a way to ensure more than the traditional sources of revenue. We didn't want to lose clients to service companies that are not producers, which we call the conservators'.*

Value exploitation also emerged as motivation since the company changed the value of an old product by providing a new related service. Adapting services also came out, with the accessibility market as a milestone. This did not involve merely a product or service launch, but entire new lines of products and, consequently, traditional services as those mentioned above were launched. Here, another market is covered by the company's mobility solutions. The principal driver was different competitive circumstances due to new legislation in effect, which opened this new market. According to the national R&D manager:

> *'The government enacted legislation to cover people with reduced mobility. From this, there was a market expansion. The market was willing to pay for the technology due to the law that emerged. So our company developed the products to serve this attractive new market. Our related services were kind of the same because of the competencies we had already developed with our old portfolio'.*

As for smoothing services, i.e., services that do not alter the product functionality, two milestones became visible in the transition phase. The first one was the company's entry into e-commerce. Based on technology already available on the market, a platform was launched, also available for smartphones and tablets, increasing the ease of access of the customer to sales. As with the accessibility milestone, the motivation mentioned emerged from competitive context changes. As stated by the national logistics manager:

> *'The big problem is that a parallel black market exists in which elevator pieces are traded without sales invoices, a criminal practice that must be restrained by condominiums and their responsible parties'.*

E-commerce emerged as an attempt to facilitate access by customers and stop other irregular sources from buying components. The risks are the lack of security related to elevator performance. The second milestone on this servitization path was telediagnosis. Some elevators have a telemetry system that allows the equipment to communicate any failures to a technical center through embedded sensors and software. Therefore, the customer does not need to go after the company, and the time needed to solve the problem is shortened since the company works proactively, thus improving product value. The great motivation here is the same as that of the first services launched by the company: to improve product performance and retain clients, but technological advancement was also mentioned as a second motivation. This has been confirmed in the literature, which shows that performance expectancy is one of the most critical determinants of consumer behavioral intention (SILVA et al., 2022).

In addition, product-supporting services (RADDATS et al., 2015) were recognized: purchases from financial governmental institutions to corporations and more product-related service, the front loaded call system. The first one amplifies the product offering through credit cards from an investment bank to incentivize corporations. The motivation for this milestone is to expand the demand for products to diversify client segments, as observed by the national marketing manager: *'We needed to facilitate the acquisition of our products by other companies such as construction companies, one of our most important segments'.* On the other hand, frontloaded call systems play the same role as a product-supporting service yet in a different way, through system product definitions (REN; YEO, 2006). A frontloaded call system may be defined as software that gathers all the same destination requests at the same cabin, optimizing end-user waiting times and the traveling capacity of an elevator. In this case, three different motivations were pointed out by the interviewees. The influence of competitors is one of them, as highlighted by the national R&D manager:

> *'There was already a patent for this innovation but not enough technology to transform it into a business opportunity. Once processor costs decreased, the competition started to launch this type of service, and our company couldn't stay behind'.*

As mentioned earlier, there was a need to improve the product to facilitate the service, resulting in client retention and the search for differentiation.

Lastly, customer-supporting services (RADDATS et al., 2015) appeared which aim to propose strategic solutions to specific customer problems. Home elevators with cabin customization, according to the national R&D manager: *'combine energy-saving solutions and bring the possibility of customizing the elevator cabin to better meet the desired aesthetics'.* This milestone had two motivations identified, with the first being the need to improve the product to facilitate the service, as observed by the junior services analyst: *'The new product positively impacted the maintenance time, and it is an excellent option to modernize later services'.* Another perspective is the need to expand the demand for products to different client segments, which the senior services analyst illustrated:

> *'People have mobility difficulties as they grow older, so the company developed a product to cover this opportunity, and the related services require the same competencies we already had'.*

The other launch was a product with two independent elevators in the same shaft. The intrinsic services are faster mobility and a different maintenance category. It renders the available space more efficient, consumes less energy, and increases capacity, transporting 40% more passengers than a traditional elevator. The motivation is a response to different competitive circumstances, as the innovation director pointed out: '*We intend to support cities, responding to urbanization requirements'*.

### 3.5.3.Servitization paths in the mature phase

Product-oriented services emerged in the company's launches. At this point, only one milestone was indicated: the failure prediction system; the national R&D manager observed:

> *'As a digital-age partner, our global service engineers and technicians receive real-time alerts for pre-issue repairs, enabling them to ensure every customer benefits from more proactive customer service'.*

As the motivation, the company was influenced by competitors and technological advancement, as the innovation director stated:

> *'There is a strong technology tendency of the Internet of Things and its applications. We decided to bring it inside our company and developed a predictive maintenance use'.*

Product-supporting services appeared in the last phase with two milestones: smart glasses applicability and self-driving delivery robots for elevator servicing. Smart glasses are used to optimize maintenance services. The technician visiting a client is allowed to show the control cabinet to a support team in the company, which assists the former in identifying problems. There are three motivations here, with the first being a technological advancement because, according to national marketing: *'smart glasses are being used to modernize training. It is also a trend behind augmented reality'.* The innovation director also pointed out that it was a response to competitors, although *'it was not direct competitors that opened our eyes to smart glasses applicability, IT companies released this technology and started this movement in other markets'.* The second motivation is the search for differentiation since it improves the quality of customer service. The self-driving delivery robots for elevator servicing are the other milestone in this servitization path. For elevator and escalator maintenance, spare parts are needed quickly, and these robots play this role, reducing waiting times and delivering any spare parts just as any bought elevator part. Considering the interviewee's viewpoint, there are two motivations for this, one is related to competitive circumstances as stated by the national logistics manager: *'Our ever-growing cities need new solutions, especially for urban logistics. Our robots are capable of substituting a fleet in ordinary traffic'.* The other is related to the search for differentiation since this type of service is not usual in this market.

Based on the collected data, a new servitization path appeared during the mature phase: use-oriented services and/or substituting services (TUKKER, 2004; CUSUMANO et al., 2015). Because their definitions are quite similar, here we consider them the same. The company launched three services that depend on products and their technology, but the product does not belong to the client after the service is provided. Theater stage platforms, power flying systems, and fire curtains play this role. The national marketing manager explained: *'We have experience installing and servicing a broad range of stage systems in theaters'.* The motivation is quite clear, as has appeared in previous research: services emerge as substitutes for products, and products play the role of services (VARGO; LUSCH, 2004; CUSUMANO et al., 2015).

Adapting services arose again in the mature phase with two milestones. Horizontal and vertical transportation in the same shaft was the first launch identified. It works as a subway station inside a building, with an elevator without cables. It is a newly provided service, directly impacting product functionality. According to the innovation director:

> *'We want to reinvent the elevator concept. We wondered: how may we save space, increase speed, and reduce waiting time? It's starting a new era of the*

> *way we see mobility. Nowadays, a skyscraper has half of its area occupied by shafts.*

It illustrates the search for differentiation as a motivation. The second launch classified here as an adapting service was the urban accelerating passageway transportation system. The national logistics manager highlighted: *'it is' a new technology that represents the company's entry into the public sector of mass transport'.* The national R&D manager complemented by stating that what motivated the company was the desire to expand the demand for products:

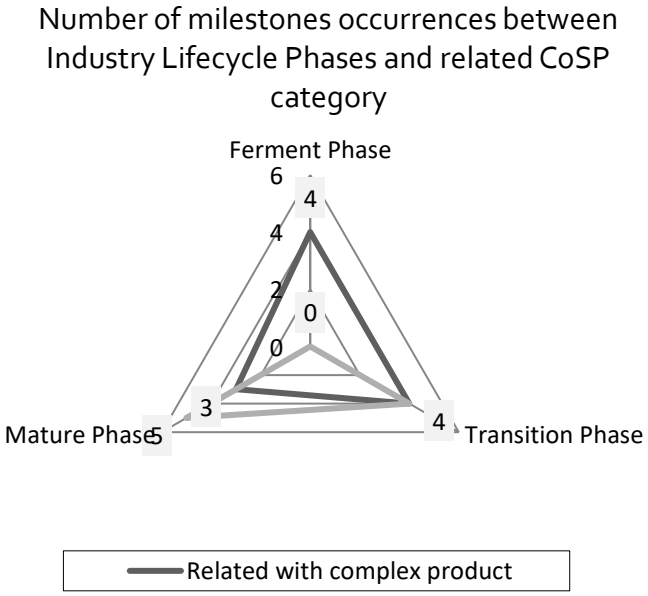
> *'[...] serving metro stations, for example, because this is an accelerating passageway transportation system that offers an efficient solution to the challenges of urbanization [...] this is a solution that bridges the gap related to people transportation in short distances'.*

The second motivation was customer retention through product improvement to facilitate the intrinsic service as well, given that it does not require complicated management and maintenance tools.

### 3.5.4.Product-centric strategy: cross-phase analysis

To explain gaps and divergences in comparison with the existing literature regarding the occurrence of some servitization paths in other phases, the milestones were analyzed according to the complex product and system (CoSP) category. In general, we observed that the trajectory is shared almost equally among CoSP categories (Figure 3.4).

Figure 3.4: CoSP category in industry lifecycle phases.




In the ferment phase, only complex products and related services were launched. This may be explained by the company's concern in this phase with a barrier in product costs and service development, as mentioned by the innovation director: *'The risk in R&D investments was too high, and the return takes too long. We decided to first stabilize with what we already had at the time'*. In the transition phase, systems started to be launched, although milestone categories were equally shared. At this point, the company started to rethink its mission, as stated by the national R&D manager:

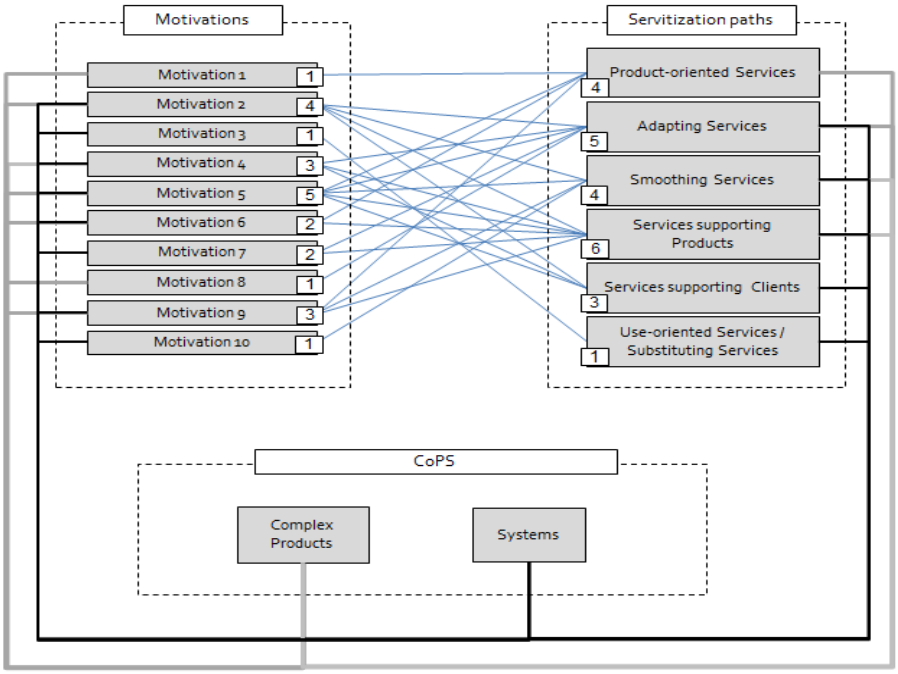
> *'Our mission is to help society achieve better mobility, and we perceived we were not merely an elevator company. Our product is a consequence of this sense of purpose'.*

In the mature phase, the number of system launches exceeded the number of complex product-related launches. As an enabler, the innovation director pointed out that:

> *'Research and development are of the highest priority for us now. It is essential for business success to protect innovation. Therefore, the company's management decided to reward good ideas from our numerous inventor teams and individual inventors. Frequently improved and developed products, processes, and services are a major premise for remaining successful in the market'.*

As the data suggests, the relationships between the identified motivations and adopted servitization paths were strictly related to the company's conduct. These relationships are illustrated in Figure 3.5, which also explores the relationship of these two variables with the CoPS categories. Each motivation was numbered and can be also consulted in Table 3.2 previously presented.

Figure 3.5: Motivations and servitization paths adopted, according to CoPS differentiation.




Motivations: (1) Diversify their revenue; (2) Respond to different competitive circumstances; (3) Emerge substitutes for products; (4) Expand demand for products to diversify the client segments; (5) Customer retention; (6) Influence of competitors; (7) Search for differentiation; (8) New market entrance; (9) Technological advancement; (10) Value exploitation.

It is worth highlighting that motivation 5 ('Customer retention'), followed by motivation 2 ('Respond to different competitive circumstances'), presented the highest numbers of relationships with five and four distinct paths, respectively, according to the interviewees' responses. These motivations, involving the concern of responding to different competitive circumstances and retaining customers, are the most related to complex products, representing the highest number of launches in the first phases. Motivations 3 ('Emerge substitutes for products'), 7 ('Search for differentiation'), and 10 ('Value exploitation') were only related to systems, which occurred because differentiation, value exploitation, and services as substitutes are the drivers of the last phase, following the company's tendency to move towards the systems value proposal, as stated by the innovation director:

> *'The trend in the market is to cheapen products; what adds value is the new technologies, and this is the sale differential. Service development grows side by side, our product means one sale, whereas the service means a contract for years'.*

Therefore, servitization paths such as client-supporting services and use-oriented/substituting services were strictly related to systems. Client-supporting services and adapting services were the most representative, and both were related to both complex products and systems. The servitization trajectory did not present some paths, such as result-oriented services and substituting services. This may be explained by the standardization rather than customization strategy (MATTHYSSENS; VANDENBEMPT, 2010; LIGHTFOOT; GEBAUER, 2011) of the company, as answered by all interviewees when asked about it.

Some barriers mentioned that might support the results and the relationship between the company's motivations and its conduct are presented next. Firstly, in the earliest phase, the product was not developed in a way to match service development, and the technicians had many problems providing good quality with the first services. Secondly, the acceptance of a new culture when using new tools and platforms for providing service was and remains a considerable barrier for employees and customers. Thirdly, the customers need to have a minimum knowledge of a technology to give it credit, and the company needs to supply this need. The last two barriers have been confirmed in the literature (CUSUMANO et al., 2015).

In contrast, the company enablers were also a variable that directly affected the results presented, primarily the team arrangement to care for the service structure within the company. As pointed out by Gebauer et al. (2010), the importance of services staff is also noteworthy in terms of a manufacturer developing a greater service orientation through its human resource management policies. Additionally, the interviewees also referenced the CEO endorsement through innovation, which is in line with Antioco et al. (2008), who highlighted the importance of the commitment of senior managers to growing the service business and leadership in terms of increasing service orientation.

## 3.6. CONCLUSIONS OF THE CHAPTER

This study investigated how manufacturing companies incorporate services in their value proposition and how the transition occurs. Through the exploration of a product-centric company that transitioned to services, the offering evolution through the servitization trajectory

was outlined, each launch of products and services was pointed out as a milestone, and patterns between the company's motivations and initiatives were identified.

As a theoretical contribution, the study presented a longitudinal case and how the service offer was built in accordance with the industry life cycle, supporting new and it answers the calling in literature to better understand the servitization journey in product-centric and manufacturing companies. The change in motivations such as offensive and defensive nature was plotted. New motivations emerged when compared with already studied trajectories in the existing literature, such as (i) entry into a new market, (ii) technological advancement, and (iii) value exploitation. Seven other motivations occurred, converging with previous research. Overall, twenty milestones were pointed out and correlated with six different servitization paths during different industry life cycle phases. The primary pattern identified was the trend in the last phase of the industry life cycle when more servitization paths were related to systems of the CoSP category rather than complex products. Three motivations were exclusively correlated with the system milestones: the emergence of product substitutes, the search for differentiation, and value exploitation. Client-supporting services and use-oriented services were servitization paths that also correlated exclusively with systems.

As implications for management, it is important to highlight that many barriers are still preventing innovation during the servitization trajectory. Product development must occur concomitantly with service development, enabling service providing and future new sources of revenue for the company. Moreover, any innovation in traditional value offerings needs support from cultural changes within the company and must be reflected in further assistance to customers. The best practices diagnosed must be emphasized and enhanced, such as the high level of leadership support in servitization initiatives within the company. Furthermore, an exclusive organizational service structure is necessary, along with the promotion of innovation programs at all levels of the work team. The standardization strategy was defined as the main driver of the transition between phases of the product-centric servitization.

The findings are limited to a single case study. Although the sample was composed of several interdepartmental insights about the company's servitization trajectory, it is necessary to extend the exploration to a larger number of manufacturing companies to extend the external validity of the findings. In addition, further research may focus on expanding the temporal view of the servitization trajectory to better understand the specific chronology of servitization paths that took place and if there is a simultaneity in two or more of them.

# CHAPTER 4 - DIGITAL SERVITIZATION AND ITS FORTHCOMING TRENDS COVERING EMERGING CAPABILITIES AND DIGITAL TECHNOLOGIES IN MANUFACTURERS: A SYSTEMATIC LITERATURE REVIEW

This chapter presents the results of phase 2 and it contains the second paper of the research which aims to identify and summarize the patterns in recent literature in the field of digital servitization, with a focus on evaluating the emerging capabilities and digital technologies. This paper applies a systematic literature review and analyzes qualitatively recent research focus, keywords, capabilities and digital technologies appearance, main studies' conclusions' directions patterns, and a new call for research for future development of digital servitization.

. Section 4.1 consists of the research method and will describe the phases followed by the authors to get to the final data, as well as the tools and criteria used for the content analysis and data storage. The following section 4.2 presents the results and discussion, where the data is shown and commented on, as well as the qualitative patterns main findings identified the research procedures for data collection and analysis, the case study selection, and context. The final section, 4.3, presents the conclusions of the present study, in which the theoretical and managerial implications are presented, in addition to the limitations and suggestions for further research.

## 4.1.RESEARCH METHOD

Following the indication of how to conduct literature review and operations management fields of study (THOMÉ et al., 2016), this work was organized and divided into the phases of (i) search query, (ii) data sourcing, (iii) screening, (iv) use of analytic tools and (v) content analysis, as illustrated in Figure 4.1. The studies were collected from the Scopus database which includes a broader range of research articles with completeness, and its metadata is available in a consistent format. Annually, more than 3 million articles were added to the Scopus database. The researchers, students, and librarians have confidence in using that database because the data from above 7000 publishers are screened independently by the Content selection and advisory board (SHAIKH et al., 2023).

The query used the strings on the search of Titles, Abstracts, and keywords according to the Scopus search formula method: TITLE-ABS-KEY ( servitization AND digitalization ),

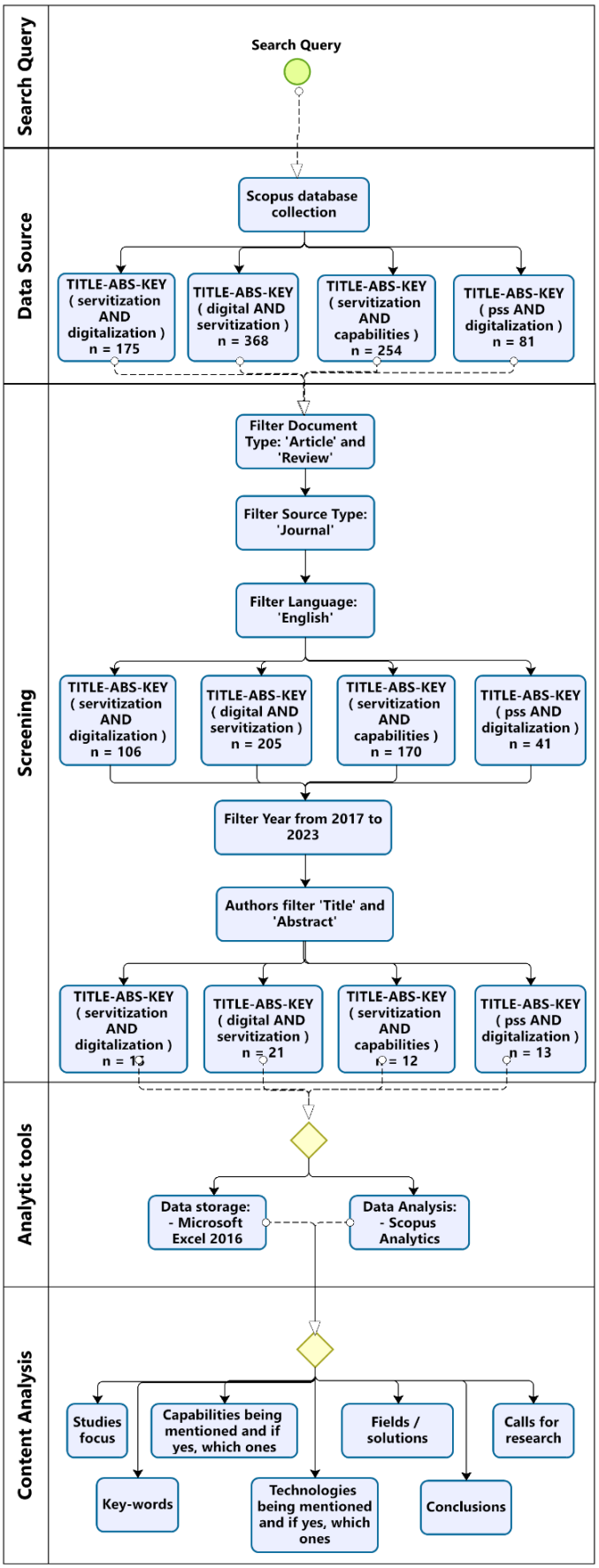
TITLE-ABS-KEY ( digital AND servitization ), TITLE-ABS-KEY ( servitization AND capabilities ), TITLE-ABS-KEY ( pss AND digitalization ) resulting in a total of 878 documents. Filters were applied to Document Type to be articles and reviews, source type was also filtered to show only Journals, and all languages other than English were excluded, resulting in a total of 522 documents. The oldest year shown with the search of the keywords was 2008. Two other filters were added to the search results. The first in the year range in order to bring only recent literature, since the study aims to bring the most recent trends. The cutting point was decided based on the data statistics of the number of documents published per year, which shows that since 2017 studies have increased considerably compared to previous years. The sample was collected until March 2023. The second filter was the qualitative screening towards titles and abstracts, the authors used the criteria of prioritizing manufacturing applied studies, and internal organizational results provided by articles, excluding studies that would focus on customer and provider relationships or supply chain processes. The purpose of this paper is to review the development of manufacturing servitization and to find a potential direction. This paper used a bibliometric method to quantitatively and qualitatively analyze the research areas, journals, countries, keywords, institutions, authors, trends, and citations of manufacturing servitization. Then, the research directions for the future development of manufacturing servitization are analyzed.

For data storage the tools used in this study were Endnote and for content organization Microsoft Excel 2017. For analytics, the data was organized through 7 codes. The qualitative analysis was segregated into seven main dimensions of the documents sample (i) what the studies are focusing on, (ii) what are the keywords statistics, (iii) if capabilities were presented and if yes which ones, (iv) if technologies were presented and if yes which ones, (v) what were the fields or types of solution in which the authors are covering, (vi) main conclusions and (vii) calls for future research. A second level of codes was created for numbers (iii) and (iv), addressing the studies for the mentioned types of capabilities and technologies, such as IoT, AI, service design, and others that will be further explained.

In the content analysis, as some groups of common data started to appear, the authors defined the main innovation fields where the studies applied such as managerial systems, business models, and PSS. In these three fields, the examples were illustrated to give the context for further analysis. For the analysis of capabilities and technologies codes, examples were collected and presented in a table format, grouping the examples into categories and main authors/studies that mentioned them. Based on this, the authors were able to visualize that

capability and technology relationships work both ways, at sometimes being inputs and outputs from each other. The fields of innovation many times overlap in different technology or capability, in many cases combining both. A framework was built to illustrate these relations, stating exactly in which fields and what capabilities/technologies were presented. The framework will be discussed in the next session. As the last deliverable of the content analysis, this work presents the main calls for research from papers published as of 2020, presented through affinity diagrams according to the common thematic. The categories found were discussed to present the main literature gaps to inspire future research.

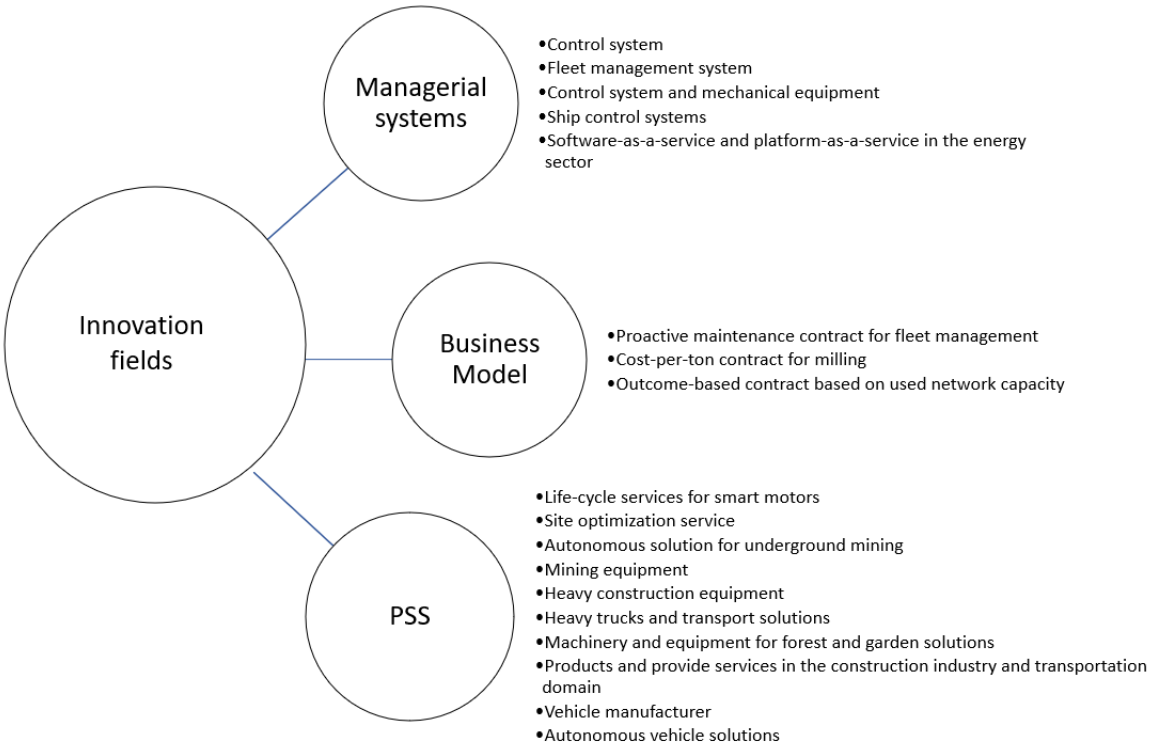
Figure 4.1: Phases of method research.



## 4.2.RESULTS AND DISCUSSION

According to the strings used - see method session, the biggest number of publications was found in 2022, totaling 167 articles, 65% more than the previous year, showing the emerging call in the subject. The string digital AND servitization started to show more results than the other two as of 2020. The majority of studies come from countries such as Sweden, China, Italy, Spain, Switzerland, and France respectively, and from fields like Business, Management and Accounting and Engineering. In total, 70 keywords appeared in the sample and the most cited keywords were digital servitization, digitalization, servitization, product-service systems, industry 4.0, and business model. The fields that emerged recently in the studies were classified by the authors according to the field of innovation, being in managerial systems, business models, or product-service system (ZHOU; SONG, 2021; LINDE et al., 2020; WEKING et al., 2020; KAMALALDINA et al., 2020; GAIARDELLI et al., 2021; KOHTAMÄKI et al., 2020; TIAN et al., 2022). Figure 4.2 shows the main fields that appeared and the classification assigned by the authors.

Figure 4.2. Innovation fields and examples of applicability.




Significant impacts of digitalization on managerial systems were shown, such as the ability to streamline operations. Digital technology has enabled managers to automate many of

their processes, which has reduced the time and resources required to complete tasks. In addition, the ability to collect and analyze data. For example, a business can use data to identify customer preferences, which can help them develop products and services that meet their customers' needs. Some of the examples of digitalization of managerial systems in the field of servitization were control systems, fleet management systems, software as a service, and platform as a service in the energy sector.

Secondly, there has been a growing trend towards servitization as companies seek to differentiate themselves from competitors and create more sustainable business models. This has led to an increased focus on business model innovation as companies seek to develop new and innovative ways of delivering services to customers, some of the cases found were the proactive maintenance contract for fleet management, cost per ton contract for milling, and outcome-based contract based on used network capacity.

At last, studies have shown that digitalization has been present mostly in the development and innovation of PSS solutions. Services for smart motors, mining equipment, and autonomous vehicle solutions are some of the cited. In light of the PSS solutions that appeared, it can be observed that we have different levels that can be explained. The three levels of product-service systems are discussed by various authors. Some of the notable authors and their works are Mont (2002), Tukker (2004), Baines, Lightfoot, & Smart (2011) Gebauer, Gustafsson, & Witell, (2011). They are the basic product-service systems, where a product is sold along with a basic service, such as installation or maintenance (vehicle manufacturer, heavy construction equipment), intermediate product-service systems, which offer a higher level of service, such as customization or personalization of the product, or additional services such as training or consulting (life-cycle services for smart motors, construction industry and transportation domain), and advanced product-service systems, which offer the highest level of service, where the product and service are fully integrated and the customer pays for the use of the product rather than owning it. This can include services such as predictive maintenance, remote monitoring, and performance guarantees.

### 4.2.1.Capabilities from digital servitization

The definition of capability can be understood as the use of resources deployed to achieve an end goal (MARCON et al., 2022; ULAGA; REINARTZ, 2011; ZHENG et al., 2019). In the sample, 35 different capabilities were identified, most cited capabilities were service design, business model innovation, and data analytics. ‘Data’ was mentioned together with many different words such as mining, analytics, integration, driven innovation, utilization,

and processing. When categorized in one word ‘Data’ it appears repetitively as much as business model innovation and service design. For Service Design, many other references were made using another notification such as product/service/PSS development (EBEL; JASPERT; POEPPELBUSS, 2022; SOLEM et al., 2022; CONG et al., 2022; WANG et al., 2021; WATANABE, OKUMA; TAKENAKA, 2020; WALL; BERTONI; LARSSON, 2020).

Capabilities were clustered according to appearance in literature and relevance to the field of innovation as Data driven, Eco-system/technology integration, Micro-service, Organizational, and Service design. Table 4.1 shows a codification of the capabilities, in which studies they are mentioned, and what examples currently are the focus of these studies.

Table 4.1: Categories of capabilities with examples.

(continues)

| **Categories of capability** | **Examples** | **References** |
|---|---|---|
| Data driven (c1) | (i) Workflow tool for simplifying scenario planning; (ii) Multichannel digital service delivery; (iii) Co-evolutionary processes and feedback loops. | Zhou & Wenyan (2021) Sjödin et al. (2021) Dalenogare et al. (2022) Schymanietz et al. (2022) Chen et al. (2022) Hussnain et al. (2020) Kamalaldina et al. (2020) |
| Eco-system / technology integration (c2) | (i) AI scaling through co-evolutionary processes and feedback loops. | Hallstedt, Isaksson & Rönnbäck (2020) Sjödin et al. (2021) |
| Micro-service (c3) | (i) Incremental microservice investments; (ii) Sprint-based microservice development; (iii) Microservice learning by doing to ensure customized and scalable digital service offerings. | Sjödin, et al. (2021) |
| Organizational (c4) | (i) Management of production/delivery operations; (ii) Development of valuable and sustainable offerings; (iii) Planning for uncertainty and change; (iv)Relationship management; (v) Prioritization of resources; (vi) Level of investment in specific assets; (vii) Knowledge sharing routines and governance mechanisms. | Tronvoll, Sklyar, Sörhammar & Kowalkowski (2020) Benedettini (2022) |

Table 4.1: Categories of capabilities with examples.
(continued)

| Categories of capability | Examples | References |
|---|---|---|
| Service design (c5) | (i) Machine learning-based iterative design approach; (ii) Pattern-based smart service innovation in manufacturing; (iii) Smart PSS in maritime industry; (iv) A machine learning-based iterative design approach; to automate user satisfaction degree. | Hallstedt, Isaksson & Rönnbäck (2020) Ebel, Jaspert & Poeppelbuss (2022) Solem et al. (2022) Cong et al. (2022) Arioli et al. (2023) |

Data-driven capabilities in servitization refer to the use of data and analytics to enhance and optimize the delivery of services. Some of the examples found in recent literature are connected with the collection and integration of data (e.g. co-evolutionary processes and feedback loops) that will generate a database for further use of the company in the decision-making process. This stage can come in different manners such as the technologies that will be further explored in this paper. Another example was an outcome of data driven performance optimization (e.g. workflow tool for simplifying scenario planning) which is the input that allows real-time data to monitor and make decisions such as resource allocation. The third example is the data drive capability of customizing the service customer-based (e.g. Multichannel digital service delivery) allowing innovation on the service delivery with tailored service models. Ecosystem and technology integration appeared as a capability in the field of AI development, specifically in co-evolutionary process and feedback loops, exploiting the interdependencies also for business model innovation.

Microservice is a term that started to appear in the last 5 years and needs to be explored. Micro-service in the context of digital servitization is a focused digital service functionality that does one thing and does it well. Accordingly, micro services lend themselves to a continuous delivery of increasingly more sophisticated digital servitization solutions (SJÖDIN et al., 2020). These micro-services are designed to work together to create a larger, more complex service offering. For example, a company that provides a digital platform for managing industrial equipment might offer microservices for monitoring equipment performance, scheduling maintenance, and analyzing data. By breaking down their services into smaller, more modular components, companies can offer more flexible and customizable solutions to their customers,

while also improving scalability and reducing development time and costs (SEPPÄLÄ; TIMO; KARI KOSKINEN , 2019; GREFEN; PAUL; KAAIJ, 2018; ROSEMANN; MICHAEL; BROCKE, 2018; RAJIV et al., 2019).

In terms of the more generic called organizational capabilities, can be found the management and capabilities connected with the high organization of the company, traditional ones need to change their approach due to the new context of digital servitization. To exemplify, the case of knowledge sharing routines and governance mechanisms shows that even though it is not a new capability to a company, its core changes drastically since the knowledge sharing is not only based on procedures and standards processes but also in the interface of systems and standard databases, unification of workflows and electronic flows within the company and even their suppliers and customers.

At last, service design, similar to data driven capability, appeared in the majority of recent studies of our sample, especially in the strings of "PSS AND Digitalization". Service design was often mentioned with the innovative approach using machine learning, in which with iterations with customers the result of the development of the service is improved.

### 4.2.2.Technologies from digital servitization

In the sample 27 different technologies were identified, most cited ones were IoT, Cloud manufacturing, big data, and digital platforms. Internet of Things is presented in the studies in connection with big data and artificial intelligence (e.g. ZHOU; SONG, 2021; WEKING et al., 2020) and with digital platforms (HALLSTEDT; ISAKSSON; RÖNNBÄCK, 2020). Table 4.2 shows the codification of technologies, the studies in which it is mentioned, and the examples of applicability.

Cloud technology was presented in a variety of software-based services in different fields such as agribusiness, logistics, e-commerce, and industrial solutions. The use of Big Data was more generically explored, giving space for further studies to analyze the applicability in innovative service offerings, other than the applicability in the customer behavior study, data management, and predictive maintenance. The technology that was found to be the biggest trend in the recent literature is Artificial intelligence, in which the innovation is on the automation of processes, which brings new functionalities to the service provided (e.g. driver assistance on fleet management or site optimization to the construction industry). The Internet of Things is usually addressed with other technologies, a possible reason behind it is that our research combined digital technologies with servitization in the strings of our method, but there is a recent study in which this technology appeared for prediction of user satisfaction in Smart PSS.

The same happens with the technology of Augmented Reality, used to traditional maintenance services transforming it into a more efficient process but also allowing a broader applicability of Engineered-to-order service offerings such as manufacturing equipment. The last technology is the digital platforms, majorly used in industry context (e.g. connection of operational systems and asset optimization). An interesting result shown is the usage of digital platforms as a part of the service offer for operational problems identification such as water leakages. Other less often cited technologies were 3d printing (WEKING et al., 2020), additive manufacturing (SJÖDINA et al. 2020), digital finance (ABOU-FOUL et al., 2021; CHEN; ZHANG, 2021), e-mobility (GOEHLICH et al., 2020), autonomous vehicles (LEMINEN et al., 2022) and rehabilitation assistive devices (JIA et al., 2021).

Table 4.2: Categories of technologies with examples.

(continues)

| **Categories of technology** | **Examples** | **References** |
|---|---|---|
| Cloud (t1) | (i) Cloud-based software for farm management with IoT; (ii) Cloud-based industrial IoT platform and consulting for industrial digital transformation; (iii) Tools on demand with guaranteed availability (Fleet Management) and cloud-based asset management; (iv) Cloud-based platform for innovating or trading goods and services among user groups. | Zhou & Song (2021)<br>Weking et al. (2020) |
| Big data (t2) | (i) Data management such as quality of data integration, secure data sharing, and data warehouse management; (ii) Predictive maintenance with data from IoT devices; (iii) Data interaction on customer behavior. | Baines & Lightfoot (2013)<br>Irene & Parry (2016)<br>Neely & Andy (2013)<br>Rajkumar (2016)<br>Grefen (2018)<br>Zhou & Song (2021) |
| Artificial Intelligence (t3) | (i) AI-enabled automation of underground loading, predictive maintenance, and mine optimization services; (ii) AI-enabled digital transformation services and automation of drilling systems; (iii) AI initiative toward delivering digitally enabled site optimization services for the construction industry; (iv) Fleet management systems, fuel efficiency, and driver assistance functionalities. | Sjödina et al., (2021)<br>Payne et al. (2021) |

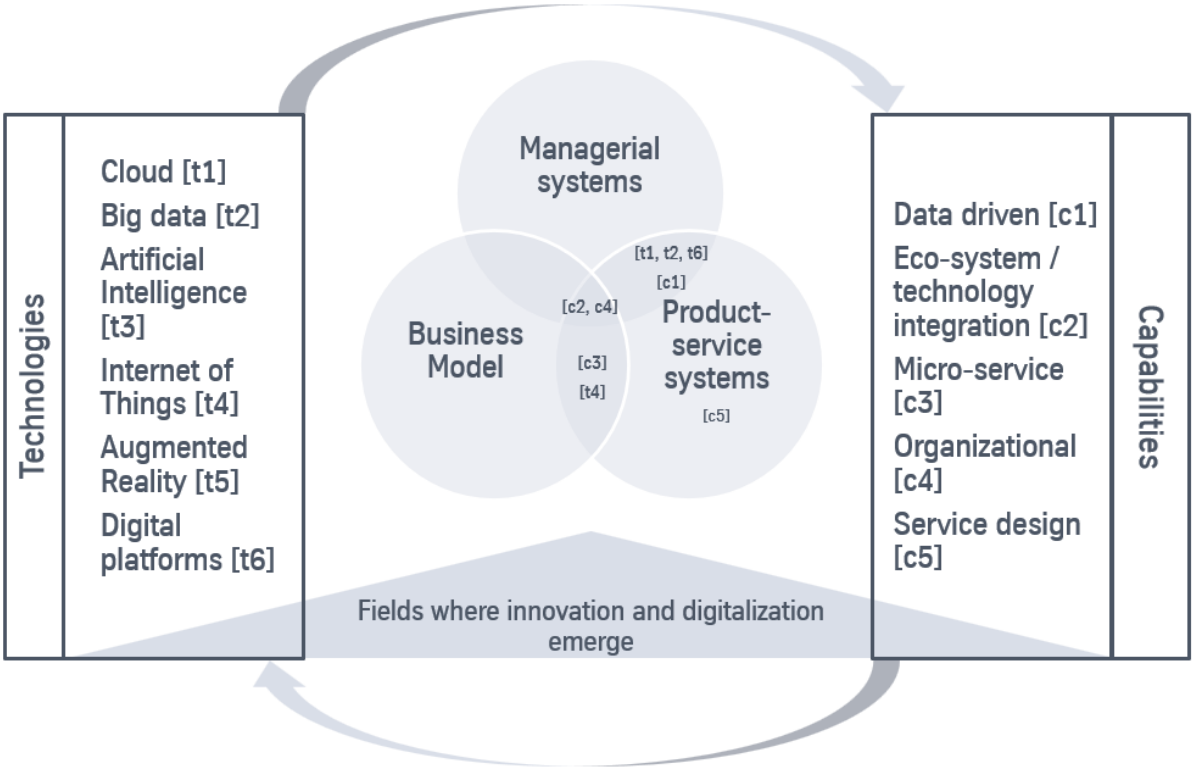
Table 4.2: Categories of technologies with examples.
(continued)

| Categories of technology | Examples | References |
|---|---|---|
| Internet of Things (t4) | (i) User satisfaction degree prediction in the smart product-service system. | Cong et al. (2022) |
| Augmented Reality (t5) | (i) Adaptive Maintenance of Engineered-to-Order Manufacturing Equipment. | Angelopoulos & Mourtzis (2022) |
| Digital Platforms (t6) | (i) Manufacturers advanced services that are integrated into tangible assets in the domains of remote monitoring, asset optimization, and workforce efficiency; (ii) Offering portfolio to industrial services for own and third-party assets; (iii) Identifying operational problems such as positions of water leakages; (iv) Digital platform was developed for connecting all operational systems. | Tian et al. (2022) Kamalaldina (2020) Eloranta (2021) |

### 4.2.3.Conceptual Framework

Not only a set of joined different capabilities were cited in specific studies, or a set of technologies, but also the mix between these sets were identified. It is observed that often, capabilities are the inputs that allow the technology to be used and put into practice in the innovation and digitalization of managerial systems, business models, and Product-service systems. Figure 4.3 presents the framework that shows the relations between the already named technologies and capabilities, supporting the fields where innovation and digitalization emerge.

Figure 4.3: Framework with association between capabilities and technologies within the groups of innovation fields.




In the innovation and digitalization of business models, capabilities such as ecosystem/technology integration, microservice, and organizational are more recurrent and relevant than technologies, even though AI and IoT are the most quoted technologies and play a part. One surprising result is the capability of data driven appears connected exclusively with on managerial systems field and PSS articles. Some explanations for that might be that (1) recent studies are focused on B2B rather than B2C, and the current data availability provides rich inputs on managerial systems value offerings, (2) data connected with PSS innovations are related to smart-product outputs (by it sensors, machine learning and other technologies), and being so, are used directly in the digitalization of the service itself. Corroborating with the above discussed, it was checked that in the field of PSS's innovation, service design is the capability shown exclusively in the studies with the PSS subject. The relationship between capabilities and technologies is based on the way organizations are using technology to improve their existing capabilities and develop new ones. In the same logic, capabilities can also drive the adoption of specific technologies. An example is an organization with strong data analytics capabilities that can invest in IoT to gather more data and in AI to develop predictive models, automate decision-making processes, and offer personalized recommendations to customers. In

this sense, capabilities and technologies are interconnected in the context of digital servitization, with capabilities driving the adoption and utilization of technologies, and technologies enhancing and expanding the organization's capabilities to deliver digital services (NEELY et al., 2019; KOWALKOWSKI et al., 2017). To exemplify the relationships illustrated in the framework, below are described the associations found in the sample and are explored further.

a) c1 x c2 x t3: Data driven capability was associated with ecosystem/technology integration capability and AI technology, being established in the results of Sjödin, D. et al (2021) that manufacturers need to transform their business models to incorporate the capabilities into their businesses, by focusing on the key principles relating to agile customer co-creation, data-driven delivery operations, and scalable ecosystem integration;

b) t2 x t4 x c1 x c5: Data driven capability was also associated with service design at the same time as the technologies of big data and the Internet of Things. Considering that IoT devices are the means that provide big data to manufacturers, these organizations are driven by the data also towards the process of product/service development improving their capability of service design. Designer professionals need to consider not only the product performance and cost but also the behavior of products and solutions and their impact over complete life cycles…This includes managing data created as a consequence of digitalization initiatives that need to be securely managed, traced, and made available ( HALLSTEDT et al., 2020). IoT was also mentioned as associated with Service design in the Smart PSS environment. Following the same logic, a large amount of data will produce massive context information, so it is necessary to complete the iterative design of a complex digital product/service in a data-driven way. All users' satisfaction degree can be predicted in real-time by using the data collected in the usage context; 2) it can identify unsatisfied users automatically and recommend personalized services to them; and 3) the proposed approach can promote Smart PSS user satisfaction by iterating the modules to enable its adaptation and extend its usage lifecycle (CONG et al., 2022);

c) t2 x t3 x t4 x t5 x c3: a variety of technologies are associated such as IoT and Big data, already explored above, nevertheless, together with AI and Augmented Reality associated with the capability of microservice. In this context, the results of Sjödina et al. (2020), in the innovation of microservices that will have those technologies, suggest that value co-creation in digital servitization is best managed

through an agile micro-service innovation approach. Such an approach requires incremental micro-service investments, sprint-based microservice development, and micro-service learning by doing to ensure customized and scalable digital service offerings;

d) t3 x t4 x t6 x c5: At last, in the context of the technologies AI, IoT, and digital platforms present in Industry 4.0, there is an evolution resulting in smart servitization, taking the place of non-digital servitization and evolved digital servitization. Because of that, service design capability needed to be enhanced. One example that illustrates this association of capability and technologies is the empirical study of Tian, Coreynen, Matthyssens, & Shen (2022) that explores how manufacturers adopt platform-leveraged thinking to implement servitization in an Industry 4.0 context and their results reveal companies' roadmaps in undertaking digital and smart servitization.

### 4.2.4.Calls for research

When looking into the calls for research of the sample collected, for the different thematic identified, an affinity diagram was used to organize the information into the main groups. Within these groups, affinity categories were plotted and arranged in combination as cited by studies' conclusions. It is important to highlight that the affinity diagram shows the affinity categories and the combination in which they are cited together in the different groups. The same arrangement can be repeated in different groups, for example, the categories success rate, decision making, multi-actor ecosystem, co-creation, and affordance dependency were cited together and repeated in the groups of the decision making process and multi-actor system. The full table with categories and respective studies is available in Annex A.

Some of the main trend presented was the need to evaluate immature markets in terms of capabilities (HUIKKOLA et al., 2022) and also interactions between start-ups and small and medium-sized manufacturers (MARCON et al., 2022). The trend to better evaluate decision making processes was connected with innovation in Smart solutions and the success rates - financial figures being cited often. When the need for longitudinal research was suggested, the new call was connected with the need to understand how the success rates are affected by a multi-actor ecosystem and presented a future opportunity to conduct longitudinal case research that explicitly explores the individual decision-making that forms part of the servitization approach (NAIK et al., 2020). In addition, different industry behavior studies were pointed out, and the call in two papers is inclined to deep dive into business models efficiency in autonomous

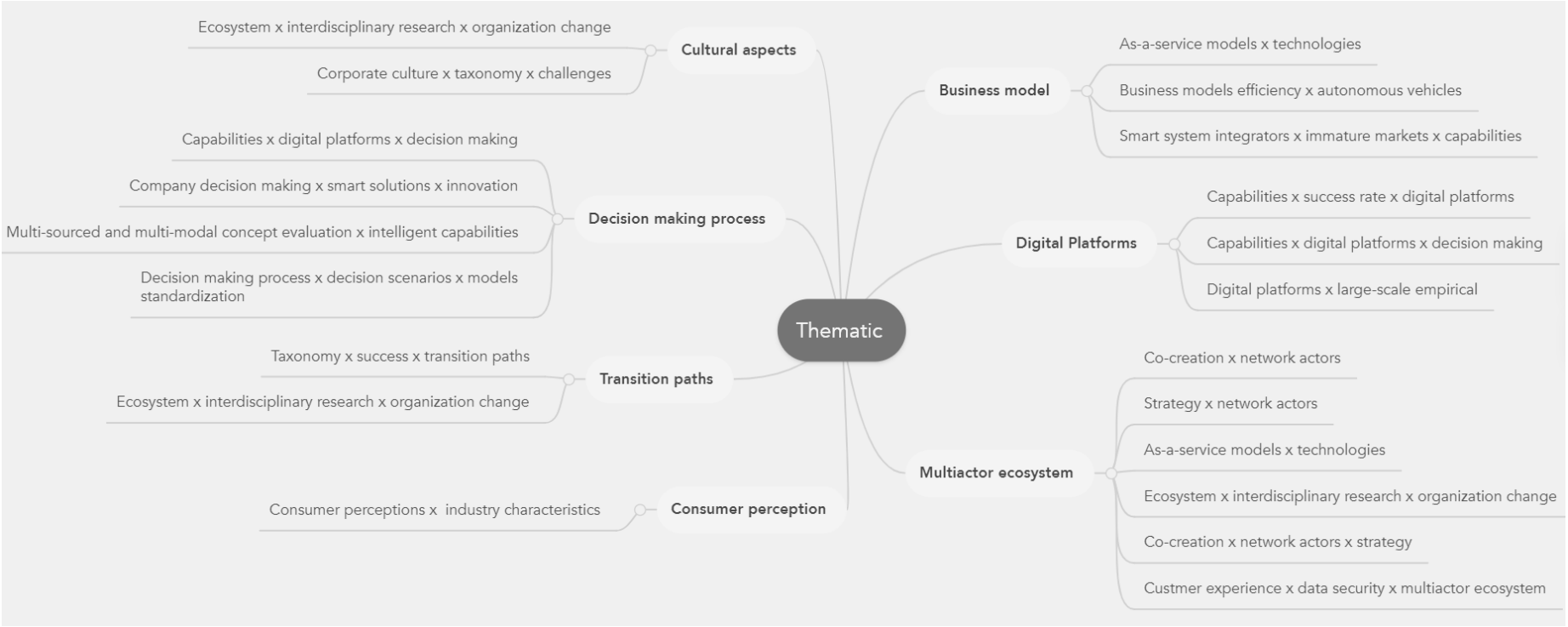
vehicles (LEMINEN et al., 2022; TURIENZO et al., 2023). Also, the need to understand platform-based-servitization in manufacturing and its different industry phases was suggested (TIAN et al., 2022).

In the thematic affinity diagram, shown in Figure 4.4, the innovations and trends are visible around groups such as cultural aspects to be evaluated in the digital servitization organization's journey, which calls for a deep dive into business models, digital platforms, and the decision making process. In addition, it was also presented suggestions to evaluate different dimensions of transition paths in the servitization trajectories, behavior of multi-actor systems, and customer perception. Exploring the emergence of digital servitization through co-creation among different network actors (e.g. providers, service delivery partners, and customers) could provide interesting multi-actor perspectives for future digital servitization research. Thus, exploring the alignment of actors to realize distinct value propositions and investigating the orchestration strategies needed to direct ecosystem actors could provide interesting multi-actor perspectives in future research.

From a sample of 39 papers where their calls for research were analyzed, 11 studies suggested trends that correlates with the purpose of our research, being (i) the need for analysis of dominant transition paths and servitization trajectories (addition of temporal dimension), also how knowledge sharing is managed along this lifecycle, especially formerly product-oriented organizations, which are more likely to struggle with the transition (WEKING , et al., 2020; TIAN et al., 2022; PIROLA et al., 2020; SCHYMANIETZ et al., 2022; MARCON et al., 2022; MÜNCH et al., 2022); (ii) the study of new trends when organizations use digital technologies in the processes and offerings related to servitization, the combination of servitization and digitalization raises new challenges that should be addressed in future research (MORAES; CUNHA, 2022); (iii) the investigation of how capabilities differ between the different business models, firms from different manufacturing industries to determine whether our model of servitization capabilities is replicable to other settings, or whether different capabilities emerge (HUIKKOLA et al., 2022; BENEDETTINI, 2022); (iv) the better understanding of success factors and what types of simple rules have managers created to run processes successfully, what experiences have taught managers for quantifying the success of servitization through conduction of longitudinal case research (HUIKKOLA et al., 2022; NAIK et al., 2020). These 4 main areas of calls are connected with the current study purpose of evaluating the trends of digital technologies and capabilities. It also shines new light supporting the need for temporal studies considering transitions, industry lifecycles, and servitization trajectories, for the

evaluation of the other factors according to changes through the temporal phases as a possible way of preparing companies for what is yet to come.

Figure 4.4: Affinity diagram for different thematic emerging on literature.



## 4.3. CONCLUSIONS OF THE CHAPTER

The results indicate that when a new digital technology emerges, the industry reacts to implement the technology in (i) its value offer delivery to customers to enhance its possibilities of creating profit and (ii) its operational processes for optimization and reduction of costs. The results show that new capabilities are developed and are key factors for the success of companies' strategies for implementing the technologies. The results also show that one technology will more often than not, be associated with others. For instance, as already described Artificial Intelligence is connected with the need also of implementing Big Data platforms. The same behavior was proven in capabilities development and the use of respective technology. For example, managerial capabilities such as knowledge sharing need to be developed for data driven usage and interface of the system, to make the most of the performance of Internet of Things technology embarked in a PSS.

As theoretical implications, this paper addressed a call for new trends when organizations use digital technologies and a deeper understanding of what capabilities emerge from digital servitization. Therefore, the current study has summarized and categorized capabilities and technologies in the context of digitalization and servitization, according to the results of recent studies in the field. The main fields where innovation and digitalization emerge together were pointed out as being business models, PSS development, and managerial systems. Within these fields of innovation, a total of 5 different capabilities and 6 technologies stood out and were exemplified with the applicability examples. In the capabilities, a new trend called microservice is being coined and it was explored in the context of digital servitization. A framework was developed, which evidences the relation observed between the different capabilities and technologies in which organizations are being strengthened and improved. The main findings in the association were summarized in main 4 groups (i) association between capabilities of data driven and eco-system/technology integration with AI; (ii) ) association between capabilities of data driven and service design with IoT and Big Data; (iii) association between micro service and the technologies AI, Big Data, IoT and Augmented Reality; (iv) association between AI, IoT and Digital platforms with Service Design capability.

For managers, the study provides evidence and insights into which capabilities need to be developed given the advance and use of determined technologies in the strategy of innovation of the servitization path. Also, the opposite direction, shows that manufacturers that are developing a product-centric servitization should also bear in mind the set of capabilities presented to drive the usage of technologies into their service delivery.

The research has limitations in terms of possible studies being left out of the sample due to the selection of strings, language, keywords, and years of publication. For further research, the trends that were found in this literature review could be applied in a case study to test the associations in the presented framework. Companies could predict which capabilities to develop to embrace the new technology in their servitization trajectory, and the success rate of this anticipation could be measured.

# CHAPTER 5 - DIGITAL SERVITIZATION AND ITS VALUE OFFER STRATEGY: A CASE STUDY IN THE AUTOMOTIVE INDUSTRY

This chapter presents the results of phase 3 and it contains the third paper of the research that aims to evaluate how the relationship between digital technologies and capabilities applies in the automotive business of a multinational manufacturing conglomerate. This paper validates the conceptual framework developed in the previous chapter and increments it based on the case study findings. Section 5.1 consists of the research method, which describes the case study selection, data collection, and sample, as well as elaborates on the content analysis steps followed. Section 5.2 categorizes and describes the data results. In addition, it discusses the findings and presents an incremented framework of digital technologies and capabilities. At last, section 5.3 summarizes conclusions and research limitations.

## 5.1.RESEARCH METHOD

To achieve the objective of this chapter, a case study was conducted with semi-structured interviews followed by content analysis. Case studies provide an opportunity to validate existing theories and frameworks in the field of servitization. By applying established theories to real-world cases, researchers can assess their applicability and effectiveness. This validation process helps in refining and improving existing theories, making them more robust and reliable. The literature review of Gebauer & Fleisch (2011) highlights the role of case studies in understanding the servitization trends in the manufacturing industry. It emphasizes the need for in-depth case studies to capture the complexities and dynamics of servitization. In addition, Parida, Sjödin, & Wincent (2019) argue that case studies are essential for capturing the complexities and challenges of servitization in the digital age. These references highlight the importance of case studies in understanding the servitization of manufacturing and the interdependent trends associated with it. They emphasize the need for in-depth and context-specific case studies to capture the nuances of servitization strategies and their impact on businesses.

### 5.1.1.Case study selection

The selected company is the same multinational conglomerate as the first case study, explored in Chapter 3, but focused on its automotive business. This business develops and manufactures high-tech components, systems, and vehicle assembly lines for the international auto industry.

It is representative in its industry, with financial figures for the fiscal year of 2022/2023 of 7.9 billion euros in sales and 266 million euros of EBIT. Worldwide the business in this conglomerate has a staff of around 32.000 employees.

This business was selected due to its digital servitization strategy in implementation and its innovative value offer reflecting the development of digital technologies in its market and new capabilities. Its value offer covers the entire automotive value chain, from the development and manufacture of high-performance components through mechanical processing to the assembly of highly complex systems. Mechatronic solutions with electronics and software developed in-house are also part of it. The automotive sector is at the forefront of adopting new technologies such as IoT, AI, and big data analytics, which are crucial for digital servitization. This makes it a fertile ground for observing the integration of digital services. The interdependencies between servitization and digitization, particularly in complex supply chains like those in the automotive industry are being pointed out in the literature (VENDRELL-HERRERO et al., 2017; PASCHOU et al., 2020).

Since the objective of the research is to evaluate the innovation in its value offer, it is important to mention that this conglomerate has filled in the year 2023 1.200 new patents and utility model applications, showing that the innovation is a result of its culture of developing technological products and services, which will be further illustrated.

### 5.1.2.Sample description and data collection

For the first step of the research, it was created a script for semi-structured interviews based on the previously developed conceptual framework. The interview protocol introduces the research objective and its context, the framework, and literature based questions. The questions consist of 4 closed-answer questions and 2 additional open-answer questions. The full document is available in Annex B. The main topics covered were:

a) What technologies were used during the digital servitization journey?

b) For each technology stated – which capabilities were developed and/or improved?

c) What innovations were a result of the digital servitization?

It was important to select interviewees who represent a diverse range of roles and perspectives within the company. This provides a comprehensive understanding of the various aspects of digital servitization and its impact on different stakeholders. The sample of interviewees' target is described in Table 5.1.

Table 5.1. Selection of interviewees and purpose.

| Interviewee position | Purpose |
|---|---|
| Operations and production managers | Insights into the operational aspects of digital servitization, such as the integration of digital technologies into existing processes, the impact on production and logistics, and the challenges faced in implementing digital servitization. |
| IT and technology managers | Understanding of the technological infrastructure and capabilities required for digital servitization. Insights into the selection and implementation of digital tools, the integration of data and analytics, and the challenges and opportunities of leveraging technology in servitization. |
| Sales and marketing managers | Needs of the customer-facing aspects of digital servitization, such as the development of new service offerings, the use of digital channels for marketing and sales, and the impact on customer relationships and satisfaction. |
| Service managers and technicians | Understanding of operationalization of digital services, such as the training and skills required, the use of remote monitoring and diagnostics, and the challenges and benefits of delivering digital services to customers. |

The profiles of interviewees are described in Table 5.2. The number was defined according to the criteria of data saturation. Data saturation can be defined as attaining the ultimate point of data collection by the researchers without adding anything to the data (Alam, 2021). The data saturation was identified once the interviewees corroborated with previous interviews and did not present new data.

For refinement of questions and to ensure clarity, it was conducted a pilot test with one interviewee, feedback was collected and interview protocol was improved. For the content analysis, a second interview with the same person was taken into consideration. Interviews were recorded and transcribed. This was part of the iterative process, strongly recommended for data analysis in single case studies (EISENHARDT, 1989).

Table 5.2. Informants profile.

| **Functional area** | **Position** | **Years in the company** |
|---|---|---|
| Innovation | Innovation Management group leader | 8 |
| Operational Excellence | Continuous Improvement Coordinator | 3 |
| Information Technology | IT manager | 20 |
| Project Management | Project Supervisor (Services) | 7 |
| Production | Team lead Production AI | 4 |
| Sales | Controlling Excellence manager | 2 |

### 5.1.3.Data analysis

For the content analysis, the steps followed were the identification of which of the technologies and capabilities in the framework were present in the product/services of the value offer. A particular advantage of content-analytical procedures as compared with other approaches to text-based analysis is the fact that it has a firm basis in the communicative sciences. The material is always understood as relating to a particular context of communication (MAYRING, 2014). When the data allow interpretations of the latent content, qualitative content analysis reveals both depth and meaning in participants' utterances (LINDGREN et al., 2020). Bearing this in mind, after data collection, the transcripts of interviews and additional company documents were organized under a coding scheme based on the theoretical framework, consistent with codes such as digital technology, capability, and innovation. Later on, new codes were created emerging from the data such as barriers and enablers. A pattern recognition was performed (EISENHART, 1989), looking for consistent relationships among variables, sequences of events, or recurring themes. Pattern recognition helps in developing theoretical propositions that are deeply rooted in the data. For all codes, the unit of analysis was based on full sentences and when connected with digital technology code, the unit considered was also single words. The coding was done by software Microsoft Excel.

From the categorization, a qualitative and exploratory approach was conducted to interpret the results and support the interpretation with the literature already explored in previous Chapters. To ensure robustness and validate findings, triangulation of data was performed through the company's documents and reports in sales and marketing materials such as official portals and intranet. At last, the original conceptual framework used in the interview protocol was reviewed and improved.

## 5.2.RESULTS AND DISCUSSION

Digital servitization in the automotive industry leverages connected vehicle capabilities, data analytics, and IoT to offer value-added services such as predictive maintenance, real-time diagnostics, and personalized entertainment. Through cloud computing and artificial intelligence, the industry can continuously monitor vehicle performance, deliver updates, and provide enhanced customer experiences. This evolution not only improves operational efficiencies and customer satisfaction but also opens new revenue streams. The results show what new applications are emerging in the case study focus of the research on each digital technology identified in literature through the conceptual framework, and it also explores the capabilities specifics from the business to allow the innovations to happen. Finally, barriers and enablers mentioned by interviewees are presented.

### 5.2.1.Digital technologies and their application in the value offer

Once primarily focused on mechanical innovations and manufacturing efficiencies, the industry is now embracing a wide array of digital solutions. The use of digital technologies available is enabling the automotive industry to offer a host of new services and products, fundamentally changing the landscape of the automotive market.

Table 5.3 presents the digital technologies and the application of their current value offer. It was also mentioned some applications are not directly sold in the value offered to end customers but are internally used by the company to enhance its capabilities. This is also explored and discussed to present a broader perspective on digital technologies' impacts for the company's servitization strategy.

Table 5.3: Digital technology presented in the business value offer.

| Digital technology | Cloud | Big data | Internet of Things (IoT) | Artificial Intelligence (AI) | Augmented reality | Digital platforms | Others |
|---|---|---|---|---|---|---|---|
| Application | Data-based service that provides a complete assessment of the use of a car | | | AI-based solution for coatings inspection | Not reported | Damping system | Machine learning : AI application to determine the surface roughness of the metal |
| | Other use of cloud services | Autonomous driving | | AI application to determine the surface roughness of the metal | | Assistance systems | Artificial neural networks: inspection for quieter steering gears |
| | Analy-sis of custom er data | Cyber-physical systems (CPS) | | Detection of foreign objects in a given image or video | | Steer-by-wire | |
| | | | | Automatic detection of people wearing personal protective equipment | | | |

Cloud computing is mentioned in the offer of services and also connected with Big Data. The use of cloud services are dedicated to offer real-time traffic information, remote services, and in-car entertainment options. Besides, the analysis of customer data and driving patterns allows the company to offer personalized services and improve product development.

It was also mentioned data-based service that provides a complete assessment of the use of a car. The new development is aimed at fleet operators such as car-sharing providers, car rental companies and leasing companies. Particularly in the case of cars with many changing drivers, damage often occurs that cannot be assigned to a specific user in retrospect. The solution has sensors that record the accelerations and movements of the vehicle in every spatial direction. For evaluation, the application sends all the data to a cloud platform. There, an algorithm trained according to the principle of machine learning evaluates the information and analyzes driving style and damage situations. Also connected with Big Data and involving the digital technology of the Internet of Things, it was mentioned the autonomous driving. Cars using data from cameras and radar devices in place of drivers can be made safe. As stated by the interviewee "*Our software engineers are working on a solution and have already tested experimental vehicles under real conditions on a test track.*". Also, an interesting innovation reported was the Cyber-physical systems (CPS).

> "*In our automotive component production, for example, camshafts and the equipment used to manufacture them form a cyber-physical system. Components and production systems communicate with each other: Each camshaft is uniquely identified and passes through production with its first and last name, so to speak*."

It also carries a large amount of data with it. For example, the customer for whom it is being manufactured, its current processing status, and the condition in which it left the last process step. Product and production communicate with the network via interfaces. In this way, the physical world of things merges with the data networks in cyberspace to form a "cyber-physical system". The goal is the "intelligent factory" that operates in a self-controlling, adaptive and flexible manner.

It was in the field of Artificial intelligence where the biggest amount of innovations were reported by interviewees. To begin with, the AI-based solution for coatings inspection on various surfaces and detecting defects or irregularities in real time, and issuing alerts when the coatings do not meet required specifications. "*Solution is based on image processing algorithms and is able to inspect different types of coatings such as paints, metal coatings, ceramics or*

*plastics*", explains the interviewee. A second application is based on a machine learning algorithm that is trained to detect and evaluate different types of surface roughness. It involves collecting datasets that can be used to train the algorithm. Images with portable microscopes of surfaces made from different materials and processing methods are used. In addition, appropriate machine learning methods such as image processing and analysis algorithms must be implemented to improve the recognition performance of the AI and make it accessible to users. The application can be used in areas such as the quality control of products or in the evaluation of materials for the manufacture of products. Application is easy to integrate into existing systems and have a high level of precision in determining surface roughness to ensure reliable evaluation. A third solution is yet in project phase, the AI solution capable of detecting foreign objects in a given image or video.

> "*The application is based on machine learning algorithm that is trained to recognize and classify different types of objects. These can be, for example, small particles, but also larger objects. The project includes the collection of data sets that can be used for training the algorithm and their annotation, as well as the development of algorithms for image processing and analysis."*

Other AI usage that is not in the value offer but it is worth to mention because it can affect operational costs and therefore costs of products and services it the automatic detection of people wearing personal protective equipment using computer vision and deep learning techniques. The interviewee reminds that "*the goal is to make workplaces safer and more efficient. The system captures video images and analyzes them to determine whether individuals are wearing the required PPE. The AI can be flexibly developed to recognize different types of PPE*."

Augmented reality was not reported in the business, but literature shows numerous applications of augmented reality (AR) being used to enhance various aspects of automotive design, manufacturing, maintenance, and customer experience. Here are some notable applications supported by academic and industry research.

Table 5.4. Application of Augmented reality in the automotive industry present in literature.

| Application | Description | References |
|---|---|---|
| Virtual Prototyping and Design Reviews | AR allows designers and engineers to visualize and manipulate 3D models of vehicle components and assemblies in a virtual environment, facilitating more efficient design reviews and iterations. This reduces the need for physical prototypes and accelerates the design process. | Ong & Nee (2013) |
| Manufacturing and Assembly | AR systems provide real-time guidance to assembly line workers by overlaying digital instructions onto physical components, reducing errors and improving efficiency. | Fiorentino, Uva, Gattullo, Debernardis, & Monno (2014) |
| Maintenance and Repair | Technicians can use AR glasses or tablets to receive step-by-step repair instructions overlaid onto the vehicle, showing precisely where and how to perform maintenance tasks. | Mekni & Lemieux (2014) |
| Employee training | AR is used to train factory workers and service technicians by simulating complex tasks in a virtual environment, enhancing learning outcomes and reducing the time required for training. | Fonseca, Valls, Redondo & Villagrasa (2016) |
| Customer Experience and Sales | AR allows customers to visualize and interact with virtual car models in showrooms or from their homes, customizing features and exploring different configurations without the need for physical vehicles. | Javornik (2016) |
| In-Vehicle AR Systems | AR Head-Up Displays (HUDs) project navigation directions, safety alerts, and other critical information onto the windshield, helping drivers stay informed without taking their eyes off the road. | Kim & Dey (2009) |

Digital platforms were also presented to cover its value offer of services and improved performance of the products. Such as the damping system, which allows the vehicle to adapt optimally to the driving situation and increases vehicle stability significantly. The product is a damper with an electromagnetically adjustable damping system. This makes the damping harder or softer as required, thus increasing driving comfort and vehicle stability. As a result, the vehicle is always optimally adapted to the respective driving situation. At the heart of the patented technology is an electromagnetically controllable separate bypass for the damping medium. This means that it offers maximum safety thanks to its high power reserves and is

suited to series production use in vehicles from numerous vehicle manufacturers. Particularly in minivans, SUVs or MPVs that tend to sway, the technology ensures greater comfort. A service provided by assistance systems is increasingly supporting the performance of driving tasks. "*They park our cars for us, keep us a safe distance from the vehicle in front, or change lanes automatically*." At last, a steering system was also mentioned. A system that no longer uses a continuous mechanical connection between the steering wheel and the front axle. Instead, electrical signals are transmitted via data cables. In addition to autonomous driving, this also enables a completely new design and use of space in the car. This is because with steer-by-wire, steering is no longer tied to a specific location, but can be adapted to the preferences of the person driving.

Other technologies were already explained in connection with already categorized digital technologies such as AI combined with Machine learning. An innovation not referred to in the conceptual framework but mentioned by the business was the development of an artificial neural network. A method in which an artificial neural network based on special rules automatically recognizes common patterns in the vibroacoustic behavior of ball screws and steering gears and thus achieves more reliable quality on gears inspections results and quieter steering gears. However, the core idea of the project is that it is not the human experts who establish the required rules, but the neural network that automatically learns them. "*To do this, we trained a neural network at first*," explains the interviewee.

> "*This means that we 'feed' it with reference data sets from steering gears and ball screws for which the quality can vary, but is generally known. In the second step, the AI recognizes correlations within the data. This allows conclusions to be drawn as to whether the quality of the steering gear will be good or bad with a particular built-in ball screw.*"

### 5.2.2.Capabilities, barriers and enablers

Capabilities were identified in each one of the categories previously presented in the interview protocol, and examples were given and are presented in Table 5.5. For data-driven capability, the analytical power to see trends in different regions in which the company have operations were key to develop solutions according to regional needs. The use of intelligence to predict maintenance volume was also highlighted. In terms of technology integration, because it is a company that has operations worldwide, the complexity of IT integration is

crucial for the success of failure of the implementation of new digital technologies in the value offer. Global alignment within the systems used, and processes to integrate will affect agility on decision-making and delivery. The company has a global IT structure for services at different levels. Integration and technology adaptation were also developed. Employees in industrial engineering are up to date in outside business in terms of technologies being implemented, attendance to conferences, benchmarks, and these kinds of initiatives.

Micro-service was reflected in the development and delivery of digital packages to customers, which means not an entire solution is closing a sales contract but also the offer of modules of a solution.

Organizational capabilities were part of the digital servitization journey as well, such as the change in organizational structure with the creation of the digitization area that communicates with the rest of departments in the company like a cross-service in a matrix org. chart. An Agile management was also developed with decision-making squads structure. Besides, use of an innovation program/committee was created.

For Service design, the involvement of several departments other than R&D when developing services and PSS was mentioned. Other capabilities explained by interviewees but not previously categorized were (i) Clear company strategy is clear for all regions (political issues) in terms of ownership; (ii) integration of customer with production process and (iii) reduced bureaucracy in processes for approving investments in innovation.

Table 5.5. Capabilities descriptions and examples.

| Capa-bilities | Data driven | Technology integration | Micro-service | Organizational | Service Design | Others |
|---|---|---|---|---|---|---|
| **Description of capability according to interviewees** | Analytical power to see trends in different regions. | Global alignment in terms of systems used – manual process to integrate – effect on agility in decision making and delivery. | Development of digital packages. | Change in organizational structure with the creation of the digitization part – cross services in a matrix org. chart. | Involvement of several departments other than R&D (logistics, manufacturing, supplies, services – all). | Company strategy is clear for all regions (political issues) in terms of ownership. |
| | Use of intelligence to predict maintenance volume, etc. | Global IT structure for services at different levels. | | Agile management and decision-making squads. | | Integration of customer with production process. |
| | | Integration and technology adaptation – employees in industrial engineering are up to date in outside business in terms of technologies being implemented, attendance to conferences, benchmarks, and these kinds of initiatives. | | Use of an innovation program / innovation committee for innovation demands. | | Reduced bureaucracy in processes for approving investments in innovation. |

Even though capabilities are in constant development and has been enablers to use the digital technologies in its value offer innovations, some barriers were brought up or the opportunity for further development. Table 5.6 illustrates the barriers identified, associated with digital technologies. In order to corroborate with the interviewee's perspective, the author researched literature if the same barriers were already found in other industries. Barriers were especially associated with Cloud and Big Data technologies.

Table 5.6. Barriers for digital technologies implementation and comparison with literature.

(continues)

| **Barriers** | **Cited in literature** | **Digital technology associated** | | | | |
|---|---|---|---|---|---|---|
| | | Cloud | Big Data | AI | IoT | Digital platforms |
| There is a large volume of data in the cloud but it needs to improve proactiveness in the use and accuracy of data/correction of inconsistencies. | Not found | *x* | *x* | | | |
| Cloud usage has some security issues for specific customers. | Wolf & Serpanos (2015)<br>Lee, Bagheri & Kao (2015)<br>Kshetri (2014) | *x* | *x* | | | |
| Old systems – strategy is substitute for new solutions and blocks the use of the old tools. | Oesterreich & Teuteberg (2016) | *x* | *x* | *x* | *x* | *x* |
| Organizational cultural change. | Heavin & Power (2018) | *x* | *x* | *x* | *x* | *x* |
| Investment is not prioritized as it is not paid for in the contracted time. | Parida, Sjödin & Reim (2019) | | | *x* | *x* | *x* |

Table 5.6. Barriers for digital technologies implementation and comparison with literature.

(continued)

| **Barriers** | **Cited in literature** | **Digital technology associated** | | | | |
|---|---|---|---|---|---|---|
| | | Cloud | Big Data | AI | IoT | Digital platforms |
| Knowledge management structure is missing. | Not found | *x* | *x* | | | |

The skill gap is referred to in the literature (HEAVIN; POWER, 2018)., but the barrier pointed out here as the proactivity and accuracy for correction of inconsistencies is new to the literature. Another barrier that was highlighted and not previously found in recent research is the knowledge structure to be missing, for spreading the knowledge of the technology to further implementation or enabling possible innovations.

A series of actions reflecting company strategy also supporting the digital servitization and allowing to overcome barriers such as (i) a reward system for innovation ideas of new uses for implemented technologies; (ii) a budget for developing new PSS projects enabling local multidisciplinary conferences from different regions; (iii) “retraining” of employees with many years of experience in the industry; (iv) integration in onboarding and system training and technology operation; (v). “Program” AI and execution of it by AI (system interaction). Multi-agent tools. Combine AI with other technologies – use as a base for the success of the other digital technologies and (vi) Senior leadership demands applicability/identification studies of existing technologies.

### 5.2.3.Conceptual framework reviewed

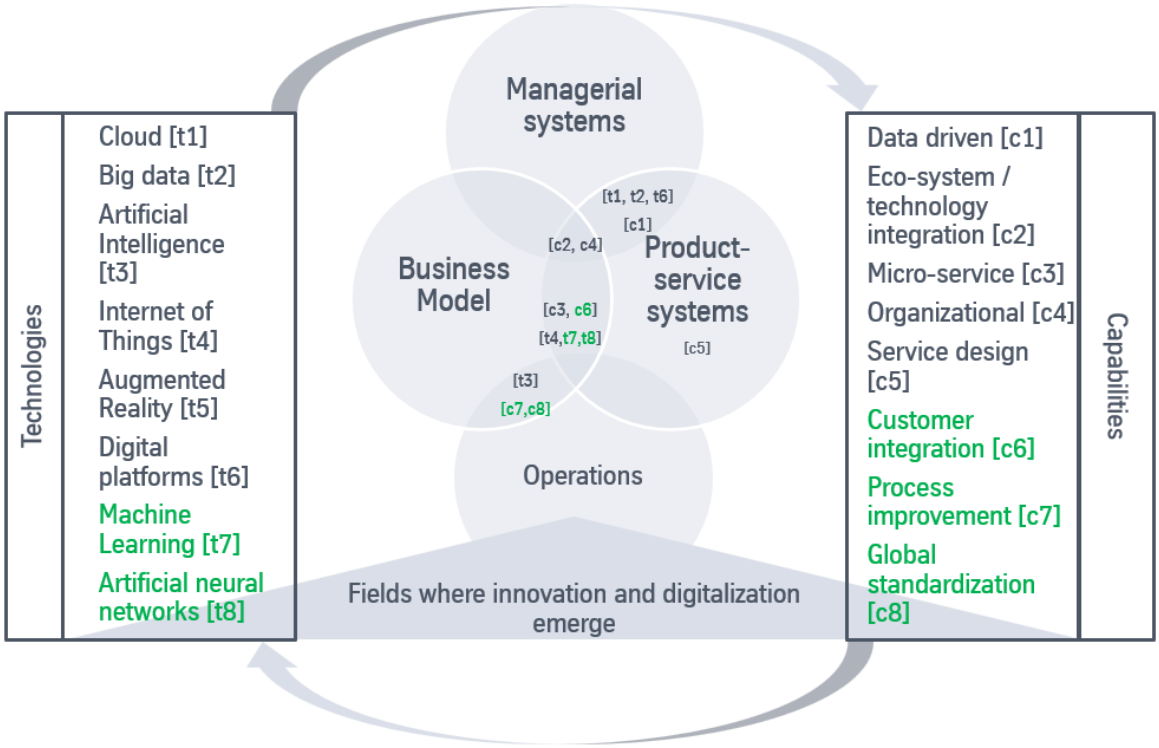
The fields where innovation and digitalization emerge were corroborated by the case study explored in this chapter. Nevertheless, a new field not previously taken into consideration is added to the conceptual framework, innovation in operations. As explained previously, some digital technologies are being implemented in the operational processes not reflecting directly the value offer but enabling, throughout the improvement of operations, the innovation in other fields to prosper. For that reason, it was included as a fourth field of innovation. As an example are the improvements in operational administrative processes such as investment approval or

production operational processes such as control of employee safety with inspection of personal protective equipment.

New findings in the feedback loop of capabilities and digital technologies were brought to light. Capabilities presented in the previous session as 'others' (Table 5.5) were categorized to compound the reviewed conceptual framework as customer integration, process improvement, and global standardization. Process improvement and global standardization were associated with the innovation of company's business model and operations. The global alignment in the company strategy to decrease political issues and the reduced bureaucracy in processes allows to streamline processes and make them more efficient and less costly, impacting on better prices to customers.

The new technologies of machine learning and artificial neural networks were found to be implemented in the innovation of product-service systems and business models, once the new value was created impacting new sources of income in the business model through the development of solutions and different product-service systems (e.g. steering gears).

Figure 5.1. Reviewed conceptual framework.



## 5.3.CONCLUSIONS OF THE CHAPTER

This chapter contributes to literature once it presents a reviewed and improved conceptual framework with the association between capabilities and technologies within groups of innovation fields. It exemplified how the relationship between digital technologies and capabilities applies in the automotive business of a multinational conglomerate, characterized by being a product-centered industry focused on digital servitization. Capabilities of customer integration, process improvement and global standardization were associated with innovations in all fields. Digital technologies of machine learning and artificial neural networks were highlighted by data collection, being associated with the innovation of product-service systems and business models.

The new findings lead to the conclusion that digital servitization is a phenomenon in constant update with emerging technologies being implemented, or the same technology being used for different applications. Product-centered firms such as automotive businesses is transforming its traditional manufacturing models into service-oriented frameworks through the integration capabilities of cutting-edge digital technologies. This shift enables firms to offer enhanced value propositions, thereby improving customer satisfaction and opening new revenue streams. A total of 13 different products/services were identified, showing enough evidence of applications. Also, 13 capabilities were described, presenting the dynamics of this relationship. Nevertheless, it can be concluded that the journey towards digital servitization is fraught with challenges such as proactiveness and accuracy on use of big data, security concerns on usage of cloud, legacy of old systems, cultural change, prioritization of investments and knowledge sharing. Overcoming these barriers requires constant review of digital servitizations strategy with actions that will enable new capabilities to emerge, fostering a culture of innovation, educating customers, and staying attuned to regulatory development.

Despite the comprehensive exploration of digital servitization in product-centered firms, this study has several limitations that should be acknowledged. In terms of scope and generalizability, the findings are primarily focused on the automotive industry and may not be fully applicable to other industries with different characteristics and challenges. Therefore, generalizations to other sectors should be made with caution. In addition, this study lacks a longitudinal perspective, taking into consideration it primarily provides a snapshot of the current state of digital servitization in the case study. A longitudinal approach, tracking changes and developments over time, could offer deeper insights into the long-term effects and sustainability of digital servitization strategies.

# CHAPTER 6 – DISCUSSION AND MAIN RESEARCH CONTRIBUTIONS

This chapter presents discussions of the findings previously described and highlights the contributions of this dissertation from theoretical point of view, and also, managerial implications.

## 6.1. SUMMARY OF THE ARTICLES' CONTRIBUTIONS

This section analyses contributions made by each chapter and respective articles developed during the research phases of this dissertation. Table 6.1 summarizes the main contributions.

Table 6.1 Summary of main contributions of research per chapter

| Chapter (article) | Main contribution |
|---|---|
| Chapter 3 (Article 1) | Identification of servitization paths in a product-centric manufacturer and the evolution of its value offer, as well as its motivations across phases of industry life cycle. |
| Chapter 4 (Article 2) | Identification of the current status and trends in literature in regards digital technologies and capabilities. Development of preliminary conceptual framework detailing relation between digital technologies and capabilities, with categorization of both and impact of innovation fields. |
| Chapter 5 (Article 3) | Empirical verification of conceptual framework and increment of factors. Practical evidence provided to corroborate literature and illustration in a case study on automotive industry new relationships, as well as barriers for digital servitization. |

In Chapter 3 (Article 1), the focus was on identifying the different paths a product-centric manufacturer undertakes in transitioning towards servitization. This involved analyzing how the manufacturer's value proposition evolved and the motivations that drove this evolution throughout various of the three stages of the industry life cycle. The contribution lies in shedding light on the specific strategies and shifts in mindset that company in this sector undergo to embrace servitization, drawing comparisons and insights from existing literature on

the subject. Servitization paths were shown to be connected with the industry life-cycle due to different motivators, which were compared to literature and new ones were identified such as new market entrance, understanding of technological advancement, and value exploitation. The advent of new technologies impact the value offer that the company has, constantly changing its strategy, launching in parallel use oriented services, adapting services, product-oriented services, and others, all co-existing in the value offer. The complexity of solutions proved that the standalone product or service do not to add enough value to customers – complex systems are developed. Specially in later stages of industry life-cycle maturity.

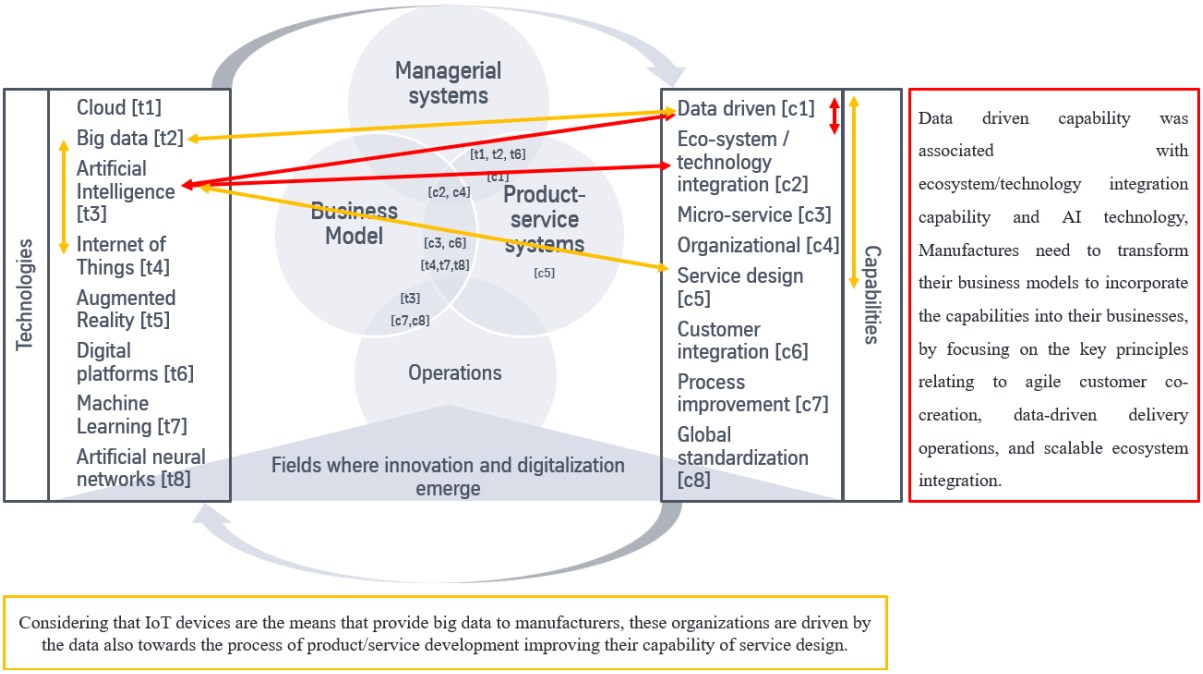
Moving on to Chapter 4 (Article 2), the emphasis was on analyzing the current landscape and trends in digital technologies and capabilities within the existing literature. The chapter sets out to construct a preliminary conceptual framework that outlines the interplay between digital technologies and capabilities. It categorizes these components and explores their impact on various innovation sectors. The key contribution lies in providing a structured overview of the relationship between digital technologies and capabilities, augmenting the understanding in this domain and providing managers of manufacturers going through digital servitization the insights on what technologies to use and what capabilities to develop in order to innovate.

Lastly, in Chapter 5 (Article 3), the primary goal was to empirically verify the previously established conceptual framework, resulting on introducing additional factors for consideration. This chapter presented practical evidence that validates the theoretical framework put forth, using a case study focused on establishing new relationships in the automotive industry and investigating the barriers present in the process of digital servitization. The significance here lies in grounding the theoretical framework in real-world scenarios, corroborating existing literature with tangible examples and insights from the automotive industry. Moreover, capabilities in the context of digital servitization are not well-defined in literature – it lacks categorization and common definition. Capabilities are often shown as secondary results and not focus of research, usually inferred. This study set ground on the capability definition as the use of resources deployed to achieve an end goal and proposes five categories based on recent literature real cases examples.

## 6.2. *CONCEPTUAL FRAMEWORK: THEORETICAL CONTRIBUTIONS AND MANAGERIAL IMPLICATIONS*

In the literature, the categories created and that are the basis for the conceptual framework were presented isolated and without clear relationships, making it harder to scholars to evaluate the impact on fields of innovation in servitisized manufacturers. The clarity on the dynamics of those relationships and already existing examples will support companies to adopt or adapt their strategies, supporting their decision making process. Figure 6.1 exemplifies the application of such scenarios using the conceptual framework developed, where the relation between capabilities of service design and data-driven categories are, for example, deeply connected with digital technologies categories of big data and IoT, in other to develop new offers incrementing service to IoT devices. Or, as a second example illustrated, how data driven and technology integration capabilities are key for the effective implementation of AI in the value offer.

Figure 6.1. Conceptual framework with example of relationships and application.




Through the empirical verification of this conceptual framework, application was incremented. The emergence of digital servitization necessitates the development of new organizational capabilities, which is a relatively new focus in the literature. Capabilities categories such as being data-driven organization, having technology integration, processes of

service design in place or even insurance of customer integration in the development of new PSSs, to quote a few, have shown to be crucial for successfully transitioning from product-centric to service-centric models. Other examples that can illustrated and further discussed on are the capabilities of process improvement, customer integration and global standardization. Process improvement involves leveraging digital technologies to streamline and enhance manufacturing and service delivery processes. Customer integration refers to the ability to engage customers more deeply in the value creation process, often through digital platforms that facilitate real-time interaction and feedback. Global standardization ensures that services and processes are uniformly applied across different regions, maintaining quality and efficiency. These capabilities are essential for companies aiming to offer consistent and high-quality service experiences worldwide.

In the other hand, the literature has started to recognize the significant impact of combining multiple digital technologies on servitization. For instance, the convergence of Internet of Things (IoT) and big data analytics creates powerful synergies that drive innovative service solutions. IoT enables real-time data collection from connected devices, big data analytics processes this information to generate actionable insights, and cloud computing provides the infrastructure for scalable and flexible data management and service delivery. The combination of these technologies can revolutionize product-service systems (PSSs), enabling more responsive and adaptive service offerings. This integrated approach enhances the ability of manufacturers to deliver value-added services and respond swiftly to changing customer needs and market dynamics.

# CHAPTER 7 - CONCLUSIONS

The phenomenon of servitization in a product-centered manufacturing environment was explored in this study. Transition paths related to the value offer and the relationship between emerging technologies and the development of new service capabilities were characterized. Despite the growing body of literature on digital servitization, emerging digital technologies are in constant change, and support decision-making by practitioners is needed, highlighting the research gap that this study addressed.

The dissertation was developed in three phases, composing thirteen steps. From a first literature review, followed by an exploratory case study, the research problem was better understood. The analysis of a product-centric servitization journey allowed the researcher to understand the status of the art of servitization typologies, companies' motivations for transitioning, and the transition paths to services and PSSs from a manufacturer throughout its industry life cycle. It was observed, during this first phase, that new digital technologies and capabilities are constantly emerging and are connected to each other. A better understanding of the current literature on digital servitization was necessary.

Continuing the line of research, in phase 2, a systematic literature review was conducted, in the context of digital servitization with the objective of identifying and summarizing the patterns in recent literature in the field of digital servitization, with a focus on evaluating the emerging capabilities and digital technologies. It was found that some fields of innovation are impacted by the emerging digital technologies, such as business models, product-service systems and managerial systems. Besides, technologies are often combined, and the development or enhancement of capabilities is also necessary. Based on the categorization of all digital technologies and capabilities found in the literature, a conceptual framework was designed to support the research progress. In phase 2, it was also confirmed that the research problem is aligned with the recent call of literature on the topic of digital servitization. The literature review provided that the study of new trends when organizations use digital technologies in the processes and offerings related to servitization, should be addressed in future research as well as the investigation of how capabilities differ between the different business models.

With the digital technologies and capabilities being identified, as well as the relationship between them and the fields of innovation, all supported by a conceptual framework, the third phase was started. It verified if the relationship between digital

technologies and capabilities applies in a product-centered industry focused on digital servitization. The study in this phase corroborated with what was previously found in the literature review of phase 2, and also shed light on new technologies used by the company focus of the case study combined with to the broad category of AI: machine learning and artificial neural networks. New capabilities were also highlighted, such as process improvement, customer integration, and global standardization. This allowed the research to review and increment the conceptual framework designed from the current literature but now applied to a case study in the automotive business. It will support managers in decision-making in digital servitization journeys.

The study's exploration of servitization in a product-centered manufacturing environment underscores the transformative potential of digital technologies in modernizing industries. By analyzing the transition paths and emerging capabilities associated with digital servitization, the research provides a comprehensive framework that helps businesses navigate the complexities of integrating service-oriented models. The findings highlight that digital technologies, for example, machine learning and artificial neural networks, coupled with capabilities like process improvement and customer integration, are pivotal in this transformation. These advancements enable manufacturers to innovate their business models, create new revenue streams, and significantly enhance customer experiences. Taxonomy and categorization of digital technologies and capabilities were lacking, for example the usage of terms as data mining, data analytics, data integration and so forth were categorized as data-driven capabilities to allow relationships to be better illustrated and understood.

On the same way, digital technologies are often collectively discussed for their capacity to provide comprehensive solutions. However, for a clearer understanding of their unique potential and how they can be effectively combined, it is essential to illustrate them as distinct technologies. This approach highlights the individual strengths and functionalities of each technology, enabling more strategic and innovative integration tailored to specific needs. As an example, on the third chapter, the case study selected showed that machine learning is considered by the company as a separate technology even though it is one of the ways for an AI solution to achieve its goal of performing complex tasks with human reasoning.

Moreover, another conclusion can be elaborated. It was understood that digital servitization is allowing companies to innovate in their managerial systems, business models and PSSs value offers and it has been presented in all kinds of industries such as energy, automotive, transport, construction, mining, shipment, machinery and others. It was also

identified that digital technologies can impact directly PSSs at first but also allow innovation of value offer indirectly, through operational optimization – for example creating real-time follow-up of productions in order that customers can track it as an added value offer added in sales contract. Another example is the service design process to be changed using big data to make the developments more accurate to customer needs and feedbacks. The study contributes to the research gap, providing insights and a framework for transforming traditional product-centric businesses into service-oriented enterprises.

At last, the data reveals several barriers to the implementation of digital technologies, each associated with specific technologies and compared with literature findings. A notable barrier not found in the literature is the need for improved proactiveness and accuracy in handling large volumes of cloud data, particularly related to Big Data. Data also corroborated with previous researches related to barriers such as security issues in cloud usage , the challenge of replacing old systems to accommodate new solutions, impacting all the listed technologies (Cloud, Big Data, AI, IoT, and Digital platforms), organizational cultural change, another significant barrier, affects the implementation of all these technologies. Overall, these barriers highlight critical areas for improvement and alignment with best practices to facilitate the successful implementation of digital technologies.

As limitations of the study, stands out the extent to which conclusions can be generalized to industries with different structures and challenges. The exploratory case studies were qualitatively analyzed and it involves subjective interpretation of textual data, which can introduce bias. The researcher's perspectives and preconceptions may influence the coding and interpretation process. It is recommended that for future research a quantitative approach for the relationships concluded of this research is performed, allowing to provide more robustness to the results. Yet, for further future research, a cross-industry analysis would allow generalization of results and make more robust the findings in the emerging digital technologies and capabilities in digital servitization. For the barriers found by companies, it would be interesting to identify what actions are being taken to overcome and bring more enablers in the digital servitization journey, throughout multiple case studies. The direction of deep-dive and proposition for taxonomy in different levels related to digital technologies and capabilities are also a need, considering the constant emerging new terms on the field of digital servitization.

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# APPENDIX A. CALL S FOR RESEARCH FROM RECENT LITERATURE.

(continues)

| Title | Author | Year | Affinity category |
|---|---|---|---|
| How AI capabilities enable business model innovation: Scaling AI through co-evolutionary processes and feedback loops | Sjödin, Parida, Palmié and Wincent | 2021 | Digital Platforms<br>Capabilities |
| The Need for New Product Development Capabilities from Digitalization, Sustainability, and Servitization Trends | Hallstedt, Ola Isaksson and Anna Öhrwall Rönnbäck | 2020 | Digital Platforms<br>Decision making |
| Leveraging industry 4.0 – A business model pattern framework | Jörg Weking , Maria Stöcker , Marek Kowalkiewicz , Markus Böhm and Helmut Krcmar | 2020 | Transition paths |
| Transforming provider-customer relationships in digital servitization: A relational view on digitalization | Anmar Kamalaldina, Lina Lindea, David Sjödina and Vinit Paridaa | 2020 | Multi Actor ecosystem |
| An agile co-creation process for digital servitization: A micro-service innovation approach | David Sjödina, Vinit Paridaa, Marko Kohtamäkia and Joakim Wincentd | 2020 | Multi Actor ecosystem |
| Autonomous vehicle solutions and their digital servitization business models | Leminen, Rajahonka, Wendelin, Westerlund, and Nyström | 2022 | Business model<br>Multi Actor ecosystem<br>Different industries behavior |
| Expansion of servitization in the energy sector and its implications | Park | 2022 | Business model<br>Multi Actor ecosystem<br>Technologies |
| From servitization to digital servitization: How digitalization transforms companies' transition towards services | Favoretto, Mendes, Oliveira, Cauchick-Miguel and Coreynen, | 2022 | Multi Actor ecosystem<br>Transition paths<br>Cultural aspects |
| Business models in times of disruption: The connected and autonomous vehicles (uncertain) domino effect | Turienzo, Cabanelas, Lampón | 2023 | Business models |

(continuation)

| Title | Author | Year | Affinity category |
|---|---|---|---|
| Task offloading in cloud-edge collaboration-based cyber physical machine tool | Wang, Guo, Yu, Liu and Deng | 2023 | Technologies |
| Enterprise Servitization: Practical Guidelines for Culture Transformation Management | Moraes and Cunha | | Cultural aspects |
| Revenue Models for Digital Servitization: A Value Capture Framework for Designing, Developing, and Scaling Digital Services | Linde, Frishammar and Parida, | 2023 | Different industries behavior |
| Becoming a smart solution provider: Reconfiguring a product manufacturer's strategic capabilities and processes to facilitate business model innovation | Huikkola, Kohtamäki and Ylimäki | 2022 | Business models<br>Processes |
| Overcoming the challenges of smart solution development: Co-alignment of processes, routines, and practices to manage product, service, and software integration | Huikkola, Kohtamäki, Rabetino, Makkonen and Holtkamp | 2022 | Processes<br>Decision making |
| Platform-based servitization and business model adaptation by established manufacturers | Tian, Coreynen, Matthyssens and Shen | 2022 | Different industries behavior<br>Digital Platforms<br>Transition paths |
| Internet of Things technologies, digital servitization and business model innovation in BtoB manufacturing firms | Paiola and Gebauer | 2020 | Multi Actor ecosystem |
| Transformational shifts through digital servitization | Tronvoll, Sklyar, Sörhammar and Kowalkowski | 2020 | Multi Actor ecosystem |
| Digital technologies in product-service systems: a literature review and a research agenda | Pirola, Boucher, Wiesner and Pezzotta | 2020 | Decision making |
| Digital servitization value co-creation framework for AI services: a research agenda for digital transformation in financial service ecosystems | Manser Payne, Dahl and Peltier | 2021 | Consumer perception<br>Cultural aspects |

(continued)

| Title | Author | Year | Affinity category |
|---|---|---|---|
| Behind the scenes of digital servitization: Actualising IoT-enabled affordances | Naik, Schroeder, Kapoor, Ziaee Bigdeli and Baines | 2020 | Longitudinal case research<br>Decision making<br>Multi Actor ecosystem |
| Multichannel digital service delivery and service ecosystems: The role of data integration within Smart Product-Service Systems | Dalenogare, Le Dain, Benitez, Ayala and Frank | 2022 | Multi Actor ecosystem |
| Exploring data-driven service innovation—aligning perspectives in research and practice | Schymanietz, Jonas and Möslein | 2022 | Multi Actor ecosystem<br>Cultural aspects<br>Transition paths |
| Structuring Servitization-Related Capabilities: A Data-Driven Analysis | Benedettini | 2022 | Different industries behavior |
| Capabilities supporting digital servitization: A multi-actor perspective | Marcon, Marcon, Ayala, Raddats and Zolkiewski, | 2022 | Longitudinal case research<br>Multi Actor ecosystem<br>Transition paths |
| Capabilities of digital servitization: Evidence from the socio-technical systems theory | Münch, Marx, Benz, Hartmann and Matzner | 2022 | Transition paths |
| The impact of digitalization and servitization on the financial performance of a firm: an empirical analysis | Abou-foul, Ruiz-Alba and Soares | 2021 | Longitudinal case research |
| A complexity management approach to servitization: the role of digital platforms | Eloranta, Ardolino and Saccani, | 2021 | Confirmatory studies<br>Digital platforms |
| A Methodology for the Design and Engineering of Smart Product Service Systems: An Application in the Manufacturing Sector | Arioli, Ruggeri, Sala, Pirola and Pezzotta | 2023 | Confirmatory studies<br>Different industries behavior |
| A context-aware concept evaluation approach based on user experiences for smart product-service systems design iteration | Wang, Chen, Li, Zheng and Khoo | 2021 | Decision making |
| The model-driven decision arena: Augmented decision-making for product-service systems design | Wall, Bertoni and Larsson | 2020 | Decision making |

# APPENDIX B. INTERVIEW PROTOCOL.

**Interview protocol used in the empirical investigation**

**Digital Technologies and Capabilities - Case study**

**Researcher involved with the study:**

Brenda Lopes Rocha. (Federal University of Santa Catarina) – brendalrocha@gmail.com

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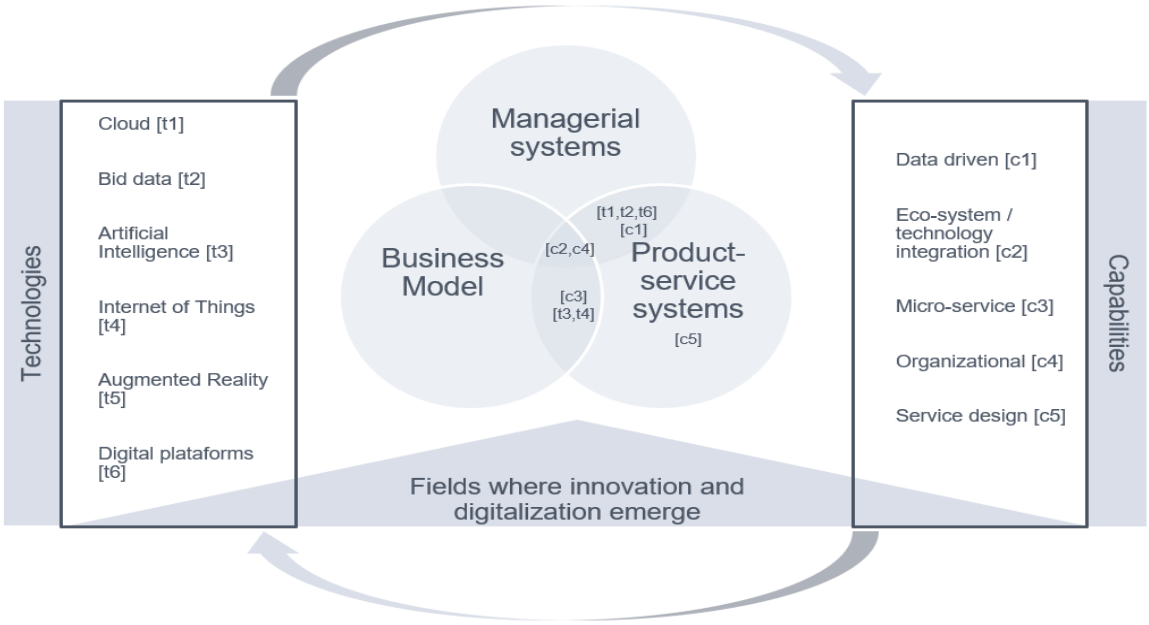
Dear Sir/Madam,

This is our research interview protocol, regarding the digital technologies and capabilities in manufacturing companies that present a servitization journey in its value offer.

Digitalization and its technologies are enablers in developing and improve the capabilities for servitization in manufacturers. The introduction of new digital technologies will stimulate manufacturers' servitization evolution and new challenges to rethink its process emerge. Among them are the changes in the design tools, the business model, and the organization, operations, and standards.

The objective of this study is to evaluate how the relationship between digital technologies and capabilities applies in a manufacturing firm, considering its servitization journey. The interview will also allow us to identify possible new relationships not previously explored in literature. It is observed that often, capabilities are the inputs that allow the technology to be used and put into practice in the innovation and digitalization of managerial systems, business models, and Product-service systems. A conceptual framework was previously developed based on recent studies and a systematic literature review. The figure shows the relations between the already-named technologies and capabilities, supporting the fields where innovation and digitalization emerge.

We would like to identify if your company has been implementing the Digital technologies and developed the Capabilities below and explore how the relationship between them occurred. New findings will contribute to improving the framework created.




The results of this interview will be compiled and analyzed. The interview will be recorded for further support of data collection analysis. The name of the company or interviewees will not be disclosed. The results of this study can be shared with you, providing you with a tool to understand which technologies and capabilities your company can use and develop further to improve your servitization strategy.

Thank you so much for your participation and contribution.
With best regards,
The researcher

## 1. Information about company

*Date of the interview: ____*
*1.1. Company's name: _____*
*1.2. Name of the interviewed: _____*
*1.3. Position/role in the company: _____*
*1.4. Department: _____*
*1.5. Time in the company: _____ years _____ months*

## 2. What digital technologies are being used for the innovations?

(Frank et al., 2019; Pirola et al., 2020; Zheng et al., 2019)

( )Cloud
( )Big Data
( )Artificial Intelligence
( )Internet of Things
( )Augmented Reality
( )Digital Platforms
( )Others – which ones?

## 3. Which innovations are these digital technologies supporting?

( )New Business Models
( )New Product-Service Systems
( )Managerial Systems

## 4. For each technology stated – which capabilities were developed and/or improved?

(Frank et al., 2019; Pirola et al., 2020; Zheng et al., 2019)

( )Data-driven
( )Technology integration
( )Micro-service
( )Organizational
( )Service Design
( )Others – which ones?

## 5. Which innovations are these capabilities supporting? And how?

## 6. What are the combinations of resources and capabilities that can lead to the success of digital servitization?

(Ardolino et al., 2018; Coreynen et al., 2020; De la Calle et al., 2020; Hsuan et al., 2021; Paiola & Gebauer, 2020).