AI-enabled sustainable business model innovation

A study of the shipping ecosystem

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By

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Acknowledgments

Sometimes I do believe there are no coincidences, when I decided to follow my interest in this topic I tried to keep myself open to the opportunities while maintaining awareness of my true interests. Somehow and almost by chance I found myself shaping a topic very similar yet also different from what I had originally proposed in my motivation letter. The moment I realized that, I knew I was on the right track for myself, not just academically, but personally.

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Despite the challenges, I am truly grateful for having followed this path and I am excited for what is yet to come. Although this chapter is coming to an end, I find comfort in the fact that no matter what, this experienced happened. In the words of one of my favourite authors, Frank Herbert: “Time can also be a place”. This moment of completion will always exist as a testament of discovery, authenticity and growth.

Executive Summary

From traditional shipping to sustainable innovation: How AI is transforming the maritime industry?

The maritime shipping industry moves 80% of global trade but faces an increasingly challenging tasks: how to achieve net-zero emission by 2050 while operating on thin margins with ageing vessels and legacy systems?

The Dutch maritime shipping ecosystem is going through a major shift. Growing regulatory pressure, including the EU Emissions Trading System and IMO's decarbonization targets, are transforming environmental compliance from a voluntary initiative into a costly obligation. Meanwhile, the industry continues to operate with fragmented value chains, limited digital infrastructure, and a widely recognized tendency to be cautious about change, coupled with intense competition that results in constrained profit margins. In search for a solution, the question that guides this research was raised: **"How can AI-driven technologies drive sustainable business model innovation within the shipping ecosystem in the Netherlands?"**

In response, this study aims to develop a comprehensive framework that guides maritime organizations through AI-enabled business model innovation while addressing the industry's sustainability aspirations. For this, a comprehensive qualitative study was conducted to capture the complex realities of digital servitization experiences. The grounded theory approach was adopted to inductively build theoretical understanding of the phenomenon rather than applying ready-made solutions that may not fit the maritime sector needs. Through 22 semi-structured interviews with decision-makers coming from 13 organizations, ranging from shipping operators to technology providers and ESG consultants, detailed data on transformation and experimentation narratives was gathered. These participants were selected through purposive sampling, ensuring accurate knowledge and representation across the ecosystem.

The Gioia methodology guided the data analysis, allowing themes to emerge organically while maintaining theoretical rigour. First-order categories were systematically generated in closeness to participants' expressions, then developed into second-order themes and aggregate dimensions that formed the building blocks of the resulting framework. This process was conducted iteratively, involving multiple coding rounds and comparison between data and emerging theory. This allowed for deeper understanding of the interviewees' experiences and further exploration of innovation dynamics within this conservative industry.

This study highlights that the innovation journey cannot be carried out in isolation, revealing nine distinct roles critical for successful transformation. While Maritime Service Operators are at the centre, broader participation of the ecosystem is essential. Digital Transformation Partners provide crucial implementation guidance, while Port & Infrastructure Managers enable ecosystem-wide coordination. Technology Developers translate AI capabilities into maritime solutions, whereas Equipment & Maintenance Providers bridge the gap between physical assets and digital systems. Moreover, Knowledge & Innovation Partners drive applied research and ecosystem connections; and Sustainability & ESG Enablers help navigate complex compliance requirements. Finally, Shipping Services Customers create necessary market demand and feedback, while Financial Institutions provide the capital and incentives

necessary. Therefore, successful innovation requires active collaboration among these roles at different stages.

The analysis led to development of the AI Sustainable Business Model Innovation Framework (AI-SBMI) framework, a proposed three level transformation approach specifically designed for the unique constraints and opportunities of the maritime operations. Unlike technology first approaches, the framework begins with comprehensive business model assessment (level 1), progresses through collaborative AI-enabled innovations (level 2), and culminates in measurable sustainable benefits across the triple bottom line (level 3), bidirectional feedback loops between levels support continuous learning and refinement across levels. This map guides organizations through the digital servitization path while maintaining the stability crucial for long-term operations.

The framework can aid achieving compelling results including fuel consumption reductions that deliver both cost savings and emissions reductions; predictive maintenance that prevents costly downtime while reducing environmental incidents; and enhanced operational visibility transforming regulatory compliance from burden to competitive advantage. Most importantly, it demonstrates that operations efficiency and sustainability are mutually reinforcing objectives, with early adopters already accessing benefits through green financing and resilient partnerships.

This research provides theoretical contributions and practical guidance for practitioners seeking structured AI adoption without compromising operational stability; for policymakers, aiming to accelerate decarbonization goals through collaborative innovation; and researchers looking to further digital servitization knowledge in conservative industries. The journey from traditional shipping to sustainable innovation requires courage, the right partners and persistence to weather the storms of change towards a maritime industry that moves global trade both sustainably and profitably.

Contents

1 Introduction

From the introduction of steam power and the telegraph for long-distance communication in the nineteenth century, to the replacement of steam engines with more efficient and powerful diesel engines in the 1930s and radio navigation, shipping has constantly driven globalization by moving goods in bigger quantities and faster across the world. After 1973, seaborne trade volume more than tripled and composition shifted from predominantly oil-based cargo to largely goods (Vaclav, 2022), which nowadays account for over 80% of the world trade (United Nations Conference on Trade and Development, 2024).

As a result, shipping (international plus domestic) accounts for over 11% of global transportation greenhouse gas (GHG) emissions in 2023 (Appendix A) and over 13% in Europe (Climate TRACE, 2024). This industry, whose emissions have risen by 20% over the last decade, runs on an ageing fleet that almost exclusively uses fossil fuels (United Nations Conference on Trade and Development, 2023) now faces targets of Net Zero Emissions (NZE) by or around 2050, including a reduction of up to 30% by 2030, and 80% by 2040 relative to 2008 (Connelly, 2023). Moreover, geopolitical tensions, conflicts and climate change have a considerable effect on key chokepoints such as the Suez and the Panama Canals. These disturbances in shipping routes extend travel distance, increase pressure on supply chains, raise costs and boost emissions (United Nations Conference on Trade and Development, 2024).

These mounting environmental pressures and decarbonization targets have prompted regulatory authorities to implement policies that translate sustainability performance into direct financial consequences for shipping operators. For instance, since the Corporate Sustainability Reporting Directive (CSRD) came into effect in 2023, companies in the European Union (EU) are demanded to report on their environmental and social impact accordingly with European Sustainability Reporting Standards (ESRS) to support sustainability and cut on carbon emissions (UN environment programme, 2024). And as governments are increasingly enforcing regulations which also have a financial impact, such as environmentally relevant taxes (European Commission: Directorate-General for Environment, 2021), sustainability has transformed from a voluntary initiative to a requirement for sustained operation (Kolagar, 2024).

The impact of regulation is particularly pronounced in markets with mature regulation enforcement, such as the European Union, where comprehensive environmental policies directly impact operational costs and competitive capacity (Fiksdahl & Wamstad, 2016). For example, as of 2024, mega container ships of 20,000 - 24,000 Twenty-foot Equivalent Unit (TEU) on the Far East-Europe route, will see an increase in costs of around $0.4 million per voyage due to CO2 emissions alone (United Nations Conference on Trade and Development, 2024). This demonstrates how sustainability has become linked to financial viability, compelling shipping companies to integrate environmental considering into their core business strategies (United Nations Conference on Trade and Development, 2024).

Faced with these mounting regulatory and financial pressures, shipping companies are compelled to seek innovative solutions that address environmental impacts and sustain competitive capacities (González Chávez, et al., 2024). Since traditional approaches to improve efficiency fall short in an industry running on thin margins, organizations are looking for alternatives that can address both economic and environmental performance in the high-tech market (Bravos, 2018). This convergence has positioned advanced digital technologies, particularly artificial intelligence (AI), as an essential tool for the maritime industry's transition toward more sustainable operations (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

These AI-driven applications are transforming maritime operations through practical developments that directly address the current sustainability and efficiency challenges. Among plenty solutions, AI is currently been applied in the industry for relevant tasks of the core of shipping operation, such as fuel optimization, predictive maintenance, route planning, and smart energy management, aside from autonomous shipping and logistics management (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). However, this is not achieved in isolation, companies that support shipping operations also invest in these technologies. For instance, port authorities invest in more efficient document management process and AI-supported error detection, which they claim has a great impact on reducing food waste and enhances the efficiency of container transport. (Vogel & Mostert, 2024).

The emergence and adoption of advanced digital technologies, such as artificial intelligence (AI) and machine learning algorithms among others, has pushed conventional businesses to move from product-centric offers to a more complex service-oriented model, this phenomenon is defined as digital servitization (Kolagar, 2024). Furthermore, servitization products can also support the realization of strategic sustainability goals. For instance, data-driven and AI-driven solutions can be seamlessly integrated into these servitization products, further enhancing their sustainability impact (Kolagar, 2024). Some examples include leveraging data for ship fuel consumption prediction models to improve energy, operating costs and emissions management, which are fundamentals steps toward regulatory compliance and the transition to zero-emission shipping (Yan, Wang, & Psaraftis, 2021), and the implementation of CO2 calculators for logistics companies for more efficient management and to make CO2 emissions transparent for their customers (ilionx, 2023).

However, achieving AI-driven and sustainability in shipping requires coordinated ecosystem collaboration rather than isolated efforts (González Chávez, et al., 2024). As discussed by Kolagar, Parida, and Sjödin (2022), the importance of ecosystem partnerships in accessing digital capabilities, resources, and innovative capacities are critical for the realisation of the capabilities of digital servitization. Moreover, for effective orchestration and implementation of digital services, at the organizational level, stakeholders should align internal factors with strategic goals and leverage business model innovation (Kolagar, 2024), which applies for adopting AI-driven capabilities. However, inter-organization collaboration raises challenges such as partners scouting, trust building and investment coordination (González Chávez, et al., 2024). Thus, to understand the dynamics of ecosystem orchestration that support or limit AI-enabled digital servitization, empirical case studies are necessary (Sjödin, Parida, & Kohtamäki, 2023).

Addressing these collaboration challenges requires specialized expertise in both digital transformation and industry specific requirements, where technology integrators emerge as a critical role for technology adoption. As indicated by Connelly (2023), collaboration, technological innovation and policies across the value chain are needed to support the adoption of low and zero-emission technologies for the industry. Nevertheless, among the barriers for successful digital transformation identified in maritime transport sector are the lack of digital skills and qualified labour, which will only get worse as new technologies with additional skills and knowledge requirements emerge. In this regard, cooperation between universities and the private sector can support the human and knowledge management necessary. (Tijan, Jović, Aksentijević, & Pucihar, 2021). This skills gap becomes more pronounced as AI technologies become increasingly more complex to implement. Companies like ilionx, an industry player in the Information Technology (IT) sector with a track record of collaboration with companies surrounding the maritime-shipping industry and supporting companies in the integration of their digital strategy with their business strategy (ilionx, 2024) play a critical role in bridging this gap, effectively supporting business model innovation.

Nevertheless, despite these emerging technological solution and collaborative frameworks, the implementation of AI-driven sustainable business model innovation remains a complex undertaking that extends beyond the availability of technological solutions and partnerships. Shipping companies face the challenge of addressing sustainability demands to meet ambitious decarbonization targets (Hargreaves, 2024) as they are also race to implement AI capabilities in their operations to foster sustainable growth and gain a competitive edge (Lavelle, 2024). This combination of sustainability demands, and digital transformation pressure creates unique complexity in business model innovation, requiring organizations to navigate technical, organizational, and regulatory challenges.

In the broader maritime landscape, the urgency of addressing these challenges becomes more pronounced when considering the economic risks associated with climate inaction. Industry leaders, financial and economic policymakers must consider for instance that some estimations have pointed at $8.4 trillion of US dollars in assets and revenues at risk in the coming 15 years in a business-as-usual (BAU) scenario for the blue economy from extreme weather events, sea-level rise, and other climate-related phenomena like El Niño, can further aggravate risks especially for less-prepared regions (Grantham Research Institute on Climate Change and the Environment, 2024). Given the stakes and complexity, developing a deeper understanding of successful implementation methods and orchestration becomes critical.

While the need for AI adoption in sustainable business models is clear (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024), existing literature in the analysis of digital transformation in the maritime transport sector by Tijan et al. (2021) suggest there are domains of digital transformation that require attention in terms of research such as the integration of the studies done on AI in the industry. Therefore, a more specific understanding of business model innovation in the shipping ecosystem is required to bridge the gap between AI technologies potential and its practical adoption for sustainability and competitive advantage.

Beyond these general gaps in AI integration, a more specific opportunity of research lies in the not so unexplored role of supporting ecosystem actors in enabling sustainable business model innovation (Bravos, 2018). Literature often highlights the role of the main orchestrator in creating partnerships to develop digital services and solutions (Kolagar, 2024); however, companies taking part in this process, different from the main orchestrator, also strive to develop new capabilities to remain competitive and find a market fit for their services. This is the case for IT services and consulting providers, which play a critical role in digital servitization efforts and whose expertise can provide actionable insights for organisations looking to introduce AI-driven sustainability solutions and scale them up (González Chávez, et al., 2024). Thus, a critical gap exists in the literature about how companies surrounding the maritime-shipping industry, such as IT services providers, not as a main orchestrator but as main source of critical knowledge, collaborate within specific ecosystems, such as the shipping industry, to enable sustainable innovation and support ecosystem orchestration (González Chávez, et al., 2024; Fiksdahl & Wamstad, 2016).

1.1 Research Objective

Modern business paradigms entail more than the offering of products or services with a demand. They also consider the internal and external demands that influence the capacity of an organisation to create and deliver value (Boons & Lüdeke-Freund, 2013). Sustainability is one of those, on one hand climate change is a global challenge that requires urgent multi-actor involvement, including businesses, prompting consumers to favour those that demonstrate commitment with sustainable practices (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). On the other, advanced technologies such as AI can support innovative offerings that address efficiency optimization, waste reduction and improvement of sustainable outcomes (Sjödin, Parida, & Kohtamäki, 2023).

Therefore, the proposed research will explore the mechanisms that enable business model innovation, considering AI technologies as a catalyst within the shipping ecosystem for the development of new digital services and solutions (i.e. digital servitization) with sustainable benefits. This will be explored through the lenses of a shipping ecosystem considering plater with different roles within the industry, particularly the role of IT services and consulting providers who support the transformational process of enhanced operational performance, regulatory compliance and reduced environmental impact.

Moreover, existing research lacks a holistic view of the impact of AI technologies on sustainable outcomes within the shipping industry for strategic decision-making and long-term collaboration. Hence, this research is relevant for generating industry-specific knowledge in a dynamic complex environment such as the shipping ecosystem in the Netherlands allowing for the generation of nuanced and actionable insights and for contributing to the academic literature on digital servitization and sustainable business model innovation.

1.2 Research Questions

Due to the disruptive impact of AI-driven technologies on businesses, this research aims to advance knowledge on business model innovation that leverages AI to achieve sustainable benefits. Furthermore, because organizations operate under diverse challenges and needs, this knowledge can help maximize the impact and adoption of AI-driven solutions across a variety of contexts. Given the opportunities and constraints, as well as the current context, mounting pressure and potential of evolving technologies as an aid for the maritime industry, the following research question is formulated:

"How can AI-driven technologies drive sustainable business model innovation within the shipping ecosystem in the Netherlands?"

This study will gather insights from various actors within the shipping ecosystem operating in the Netherlands to understand their roles and perspectives regarding AI-driven sustainable business model innovation. To this end, the following concepts must be further explored.

To identify the foundation for the analysis and elements of the existing of business models more suitable for innovation.

RQ1: *"What characterizes the current business models within the shipping ecosystem?"*

To understand the potential of AI-driven technologies for digital servitization through business model innovation in relation to the specific needs of the shipping industry.

RQ2: *"How AI-driven technologies can impact value creation, delivery and capture in the shipping ecosystem?"*

To explore in depth the sustainable benefits that these technologies can produce for the different stakeholders within the shipping ecosystem.

RQ3: *"What are the sustainability benefits of adopting AI-driven technologies?"*

1.3 Reading Guide

The following reading guide is provided to assist you navigate through this thesis and enhance your understanding of each chapter included in the report.

The document follows a systematic journey from problem identification to solution development and implications discussion. Each chapter builds upon the previous one, creating a cohesive argumentation that culminates in a practical framework designed for traditional, asset-heavy industries like maritime shipping. Chapter 1 introduces the problem and formulates the research questions and objectives. Chapters 2 and 3 establish the theoretical and methodological fundamentals. Chapter 4 presents findings and directly addresses each sub-question through empirical analysis. Chapter 5 synthesizes findings into the framework that serves as a comprehensive answer to the main research question. Finally, Chapter 6 concludes with implications and contributions.

The visual overview in figure 1.1 highlights the key contributions of each chapter and shows where research questions are addressed

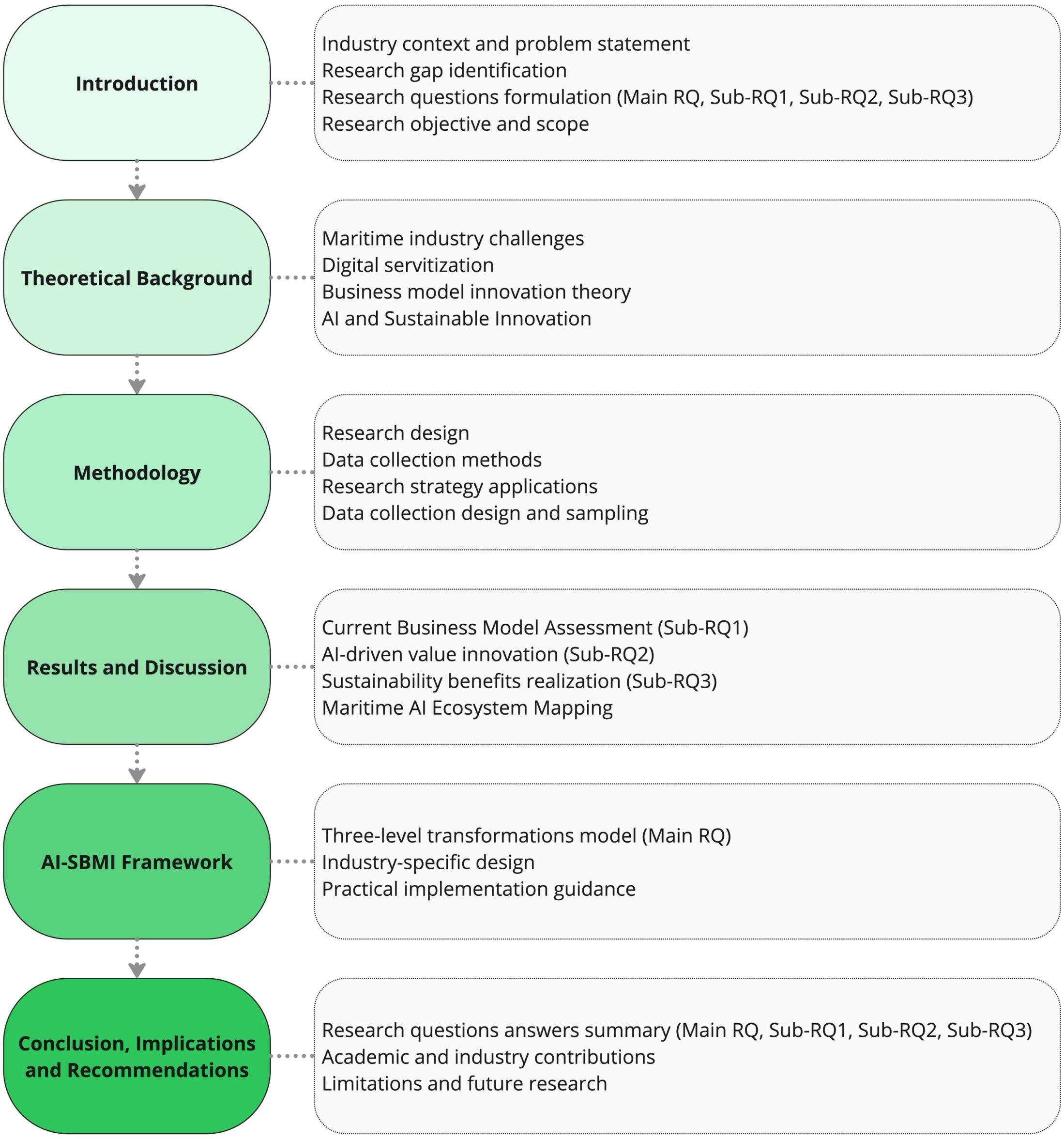

Figure 1.1. Reading guide (Self - illustration)

2 Theoretical background

This research draws from insights in the literature of digital servitization (Chen, Visnjic, Parida, & Zhang, 2021), ecosystems collaboration (Favoretto, Mendesa, Oliveira, Cauchick-Miguel, & Coreynen, 2022), and sustainable business model innovation (Sjödin, Parida, & Kohtamäki, 2023) to explore how AI-enabled solutions can support sustainable business model innovation in the maritime context. To establish this theoretical foundation, the chapter first examines the specific challenges the maritime industry currently faces that could benefit from business model innovation. Then it progresses into the core theoretical concepts, from digital servitization and business model fundaments to their integration into AI-enable business model innovation and collaborative work. In this way, building a comprehensive theoretical foundation for the research.

2.1 Maritime Industry Challenges and Innovation Opportunities

Given the emerging character of this field of study, there is a limited amount of research on industry specific challenges and how AI-driven solutions should be tailored for the maritime context. Much of the existing research focuses on the general application for the manufacturing industry (Kolagar, 2024; Sjödin, Parida, & Kohtamäki, 2023). However, specific knowledge from sectors like the shipping industry is still limited (González Chávez, et al., 2024), which has its own unique operational and environmental challenges. Public information emphasizes market trends, such as top performing companies harnessing the power of AI/ML applications for enhancing productivity rather than generate efficiency or cost savings, as their key focus to sustain business growth (Lavelle, 2024). This research gap is particularly relevant for specific contexts like the Netherlands, which has its own regulatory environment as well as complex market dynamics due to being a hub for shipping and logistics.

The research limitations become more pronounced when considering sustainability requirements that define the current context of maritime shipping operations. The sustainable industry paradigm emerges from the synergies of intelligent production systems with strong horizontal and vertical connections across the value chain (Kolagar, 2024) to optimize resource utilization, reduce waste, and promote innovation that aligns with long-term ecological and social objectives (Sjödin, Parida, & Kohtamäki, 2023). Sustainable development strives to balance three critical factors: social, economic, and environmental sustainability, often referred to as the "triple bottom line", emphasizing equal consideration of people, planet, and profit. However, other approaches prioritize ecological and social considerations as the foundation for economic success, stressing the dependence of economic systems on ecological integrity and societal well-being (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024).

A broadly used term in the maritime industry for the sustainable ocean economy is the ‘blue economy’. Although there is no universally agreed definition, it mainly encompasses economic activities associated with the ocean, seas and coastal regions. It encompasses industries such as shipping, offshore energy, fishing, and port operations, emphasizing the preservation of marine ecosystems and responsible natural resources usage. Sustainability is therefore not only an environmental concern but also a strategic consideration for maritime stakeholders seeking to align with global climate goals, including the United Nations Sustainable Development Goals, particularly goal 13: Climate action and goal 14: Life Below Water (Grantham Research Institute on Climate Change and the Environment, 2024).

These sustainability pressures have been translated into concrete regulatory mechanisms that reshape the industry operations and create innovation opportunities. For instance, sustainability in the shipping industry is currently being shaped by external regulation pressure, such as the European Union Emissions Trading System (EU ETS). Since its extension to the maritime sector starting in 2024, companies in the industry operating within the EU are assigned "allowances" for their CO_2 emissions and any excess of the emission is subject to payment (European Parliament and Council of the European Union, 2024; European Parliament and Council of the European Union, 2023). Which in the short-term increases operational costs, but also incentives the adoption of more efficient energy management practices and investment in technology to reduce emissions.

Furthermore, the International Maritime Organization (IMO), following the Initial Strategy on the reduction of Greenhouse Gas (GHG) emissions from Ships adopted in 2018, has updated the 2023 Strategy on the Reduction GHG Emissions from Ships, which establishes ambitious targets to reduce carbon intensity by 40% by 2030 and achieve net-zero emissions around 2050 (International Maritime Organization, 2023). This regulatory framework coupled with more focused efforts such as the ETS represent both challenges and opportunities with the shipping value chain, especially in highly regulated environments such as the European Unions. Nevertheless, sustainability compliance requirements can also serve as the foundation of business model innovation, pushing the industry towards a cleaner and more resilient future.

Nevertheless, current technology developments to reduce emission are still insufficient to completely mitigate their effect. For instance, although hydrogen is a promising alternative for carbon-neutral fuel supply in the industry, its low energy density makes it challenging for storage solutions, especially for long voyages (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). Another incumbent solution to this challenge is the application of "scrubbers", devices that capture emissions directly from the exhaust pipes from the vessels and prevent sulphur oxides from being released into the atmosphere. However, these devices employ seawater to capture these pollutants and then release it back into the ocean, which is currently discussed has a detrimental impact on the maritime environment and the human activities (Romero-Martínez, et al., 2024). The technological limitations combined with regulatory and sustainability pressures create multiple opportunities for exploring innovative AI-enabled solutions that address multiple challenges simultaneously.

2.2 Digital Servitization: Technology Enabled Value Creation

An emerging phenomenon to address these multiple challenges, from regulatory pressures to technological limitations, is digital servitization (González Chávez, et al., 2024). Digital servitization entails a shift in the organization's value proposal from a product-centric model to a service-centric model supported by digital technologies (Sjödin, Parida, Kohtamäki, & Wincent, 2020). Moreover, as described by Chen et al. (2021), servitization is characterized by a transformation in the architecture of the value creation, delivery, and capture mechanisms, which in many cases requires digitalization efforts running in parallel within an organization and their convergence is described as digital servitization. This transformation tackles many of the shipping industry innovation requirements by enabling companies to move beyond traditional physical asset provision and utilization towards technology-enabled service offerings that can better respond to evolving demands by customers, sustainability and regulation (Favoretto, Mendesa, Oliveira, Cauchick-Miguel, & Coreynen, 2022).

The successful implementation of digital servitization requires the collaboration of multiple partners within an ecosystem to produce a solution that improves their competitiveness through some form of collective effort (Kolagar, 2024). To that end, the concept of ecosystem orchestration is crucial for understanding the inner mechanisms of the ecosystem (Gupta, Panagiotopoulos, & Bowen, 2020), particularly for AI-enabled business models, where more research from multiple stakeholders' perspectives is needed (Sjödin, Parida, & Kohtamäki, 2023). This ecosystem perspective is especially relevant in the maritime industry, where shipping companies, port operators, technology providers, and regulatory entities must collaborate to address complex challenges such as those mentioned in 2.1.

Moreover, advanced digital technologies such as machine learning (ML) algorithms, cloud computing, and AI, play a crucial role in the process of digital servitization due to their capabilities for data-driven innovation to create better digital services and solutions (Kolagar, 2024). For instance, AI can enhance market performance and decision-making speed by optimizing supply chain networks and improving customer experiences (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). However, a tool is only of help if its users know what it is good for, thus, business model innovation frameworks can further explain how a firm can employ AI technologies to collaboratively create, deliver, and capture value from innovative solutions with industrial partners (Sjödin, Parida, & Kohtamäki, 2023).

Therefore, the relationship between digital servitization and sustainability outcomes presents both opportunities and challenges that are relevant for the shipping industry. On one side, some research frames the implementation of sustainability practices as an outcome of digital servitization for business model innovation. For instance, emphasizing the potential of AI to optimize resource use and reduce waste, leading to circular business models (Kolagar, 2024) as well as the application of AI technologies for improved sustainable performance (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). Which suggests that digital servitization can directly contribute to address emission reduction targets and efficiency requirements imposed by evolving regulations such as the EU ETS and IMO standards discussed.

However, other contrasting approaches however argument that the use of AI alone cannot be expected to be sustainable by default, but AI needs to be tailored to reach this objective by an active coupling of strategic objectives of sustainability and AI (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). This perspective highlights the need for intentional design in digital servitization initiatives, particular in industries such as the maritime shipping sector. Understanding how digital servitization can systematically target maritime challenges requires examining the fundamental structure of business models and how they be strategically innovated to achieve these multiple objectives.

2.3 Business Models Fundaments

The business model concept is central to the understanding of how organizations operate within an environment and serves as the foundational framework through which digital servitization initiatives can be structured and implemented (Chen, Visnjic, Parida, & Zhang, 2021). While many definitions of this concept exist in the literature and serves distinct purposes depending on the stage of development of an organization, a basic structure prevails framing it as a conceptual tool used to understand how a firm conducts business and supports performance evaluation, management and innovation (Boons & Lüdeke-Freund, 2013).

A business model describes the functioning of a firm as a system to create, deliver and capture value for its stakeholders, providing a holistic description of its intended operation (Matricano, 2020). Therefore, a business model can be seen as a set of crucial functions and architecture that describe how a company operates. However, this shouldn't be confused with strategy. While the business model refers to the system and principles that are the foundation of a business value creation mechanisms, the strategy refers to the choices and actions to be implemented to operationalize the business model. (Matricano, 2020). This distinction is particularly important as organization must first establish structural foundations of their value systems before implementing specific technological and collaborative strategies (Di Vaio, Palladino, Hassan, & Escobar, 2020).

As for the building blocks of a business model, starting with value creation, this refers to the processes through which a company converts resources and capabilities into an element considered valuable in a market in the form of products or services (Bocken, Short, Rana, & Evans, 2014). Next, value delivery describes the methods and channels used to transfer the value created to its customers and users (Matricano, 2020). Thus, the delivery involves processes related to supply chain, order processing, customer support and order fulfilment, among others. Finally, value capture involves the mechanisms by which a firm earns revenue from the value created and delivered (Bocken, Short, Rana, & Evans, 2014). This includes pricing, cost structure and financing tools designed to generate economic return. In addition, for a sustained operation, this requires appropriate governance mechanisms that ensure the value captured is greater than the cost of realization, so the excess can be distributed among actors involved such as providers, customers and partners (Sjödin, Parida, Jovanovic, & Ivanka, 2019).

These building blocks provide the structural foundation on top of which business model innovation can occur, particularly when organizations need to adapt to changing market conditions, regulatory requirements, and technological opportunities as those faced by the shipping industry.

2.4 Business Model Innovation

The key concept of business model continues to evolve as market and social trend change and new technologies emerge. As it's the case for social responsibility and sustainability on business model design and innovation (Boons & Lüdeke-Freund, 2013). To better understand the way a business model may evolve this is described in 3 parts. Value creation, which is the added benefit that a product or service brings to the customer. Value delivery describes how this value reaches the beneficiary. Finally, value capture refers to the mechanisms that generate revenue for the organization to sustain itself financially from the value it creates and delivers (Matricano, 2020).

Business model innovation (BMI) refers to the non-trivial changes to the key elements afore mentioned and the architecture linking these elements. As described by Bocken et al. (2014) it involves changing 'the way you do business', rather than 'what you do', extending beyond process or product modifications. It is the deliberate development of novel ways to create, deliver and capture value by changing multiple components of the business model. The success of BMI is dependent on the continuous alignment of value creation and value capture mechanisms across the model (Sjödin, Parida, Jovanovic, & Ivanka, 2019).

Furthermore, this evolution is regarded as crucial to a firm to maintain competitive advantage. Since it allows the business model to adapt to the evolving customer needs and the changing business environment (Shakeel, Mardani, Chofreh, Goni, & Klemeš, 2020) often also driven but new technologies and the success is dependent on the capacity of a firm to fit the novel technology within an innovative business model (Matricano, 2020). In the maritime context, this integration involves incorporating AI technologies not merely as operational tools but also as enablers of entirely new value propositions.

Importantly, it is also emphasized that a business model innovation is often supported by multiple stakeholders, thus a broader value-network perspective is necessary for innovation of the business model (Bocken, Short, Rana, & Evans, 2014). This stakeholder interdependence is visible in maritime shipping operations, where shipping companies, port operators, technology providers, regulatory bodies, and customers must collaborate to achieve meaningful outcomes (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). However, this process carries inherent risks that require careful management, since it can destroy value rather than create it (Matricano, 2020), therefore several alternatives as well as potential adaptations should be explored. Understanding how these innovation dynamics can affect AI-enabled sustainable innovation requires examining the integration of artificial intelligence capabilities within business model innovation frameworks.

2.5 Harnessing AI to Innovate Business Models in Maritime Context

Sustainable Business Model Innovation (SBMI) focuses specifically on addressing pressing environmental and societal challenges and contribute to sustainable development by creating positive or reducing negative impacts for the environment and society. The concept is closely related to the concept of Sustainable Business Model (SBM), which incorporates a triple bottom line approach (economic, environmental, and social) to a business purpose and processes as part of their competitive advantage and considers a wide range of stakeholder interests. The relevance of SBMI lies in its potential for innovation of value creation, delivery, and capture beyond purely economic value to aid in solving environmental and social problems (Shakeel, Mardani, Chofreh, Goni, & Klemeš, 2020).

Moreover, SBMI is considered a system-level change that affects the entire business model; however, it also calls for changes in a combination of specific components, which can range from incremental improvements to more radical transformations. SBMI is driven by factors such as growing environmental concerns and awareness, changing customer expectations and technology advancements. For example, the reduced cost of solar technologies and their expansion to new markets and applications, such as the use of solar cookers in developing countries. Moreover, models such as the Blue Economy encourage broader perspectives in which ocean-related economic activities are concerned with sustainable considerations to help solve global problems For instance, the usage of biofuels, to support food supplies as a sustainable alternative (Bocken, Short, Rana, & Evans, 2014).

Additionally, data-driven innovation is a fundamental mechanism for leveraging AI for digital initiatives within SBMI. Data-driven innovation applies advanced statistical methods to machine-readable data in order to extract valuable insights (Kolagar, 2024). AI takes these capabilities to higher levels to identify patterns, trends, and anomalies in large complex data sets beyond human processing capacity. This considerably increases companies' ability to understand customer behaviour, estimate future needs, and improve services (Sjödin, Parida,

& Kohtamäki, 2023). Thus, AI's ability to transform raw data into actionable intelligence becomes a critical asset.

The maritime industry has already conducted efforts into the application of AI technologies for improving operational efficiency and sustainable operations. Current developments include solutions ranging from AI algorithms for route and fuel usage optimization, predictive maintenance systems for more efficient performance of vessels, smart infrastructure for ports to optimize energy usage for both the port and vessels docked, and even autonomous shipping and navigation systems (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). Case studies from the Port of Rotterdam are a clear example of this application (Vogel & Mostert, 2024).

However, the implementation of AI in the maritime sector faces a wide range of challenges that extend beyond technical considerations for SBMI. For once, the reliance on legacy systems and the high cost associated with adequate infrastructure, as well as shortage of skilled personnel (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). Similarly, the complexity of navigating different sets of international regulation and the complexity of integrating AI solutions into regular operation also present a barrier for adoption (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). These challenges are heightened by the simultaneous needs to address sustainability objectives while maintaining economic viability and complying with evolving regulatory framework.

Moreover, there is still a considerable lack of understanding around how to use these technologies for concrete business model innovation to create sustainable value as well as the challenges and drivers associated with the implementation of AI-enabled solutions in real-world settings (Sjödin, Parida, & Kohtamäki, 2023). For instance, some literature highlights that AI initiatives are mainly carried out with a focus on internal processes and capabilities, and the need to prioritize the usage of internal resources to protect internal organizational skills and capabilities (Kolagar, 2024). While other initiatives focus on external resource development to possibility enrich the firm with new external perspectives and knowledge as well as sharing resources with other partners (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). Therefore, although AI-enabled business models are more frequently discussed in digital servitization literature, their impact on sustainability requires further exploration (Sjödin, Parida, & Kohtamäki, 2023).

In this regard, Artificial Intelligence shows significant potential for promoting sustainability within the maritime sector, specifically in shipping and port operations. AI applications can address emissions, optimize energy use, and enhance operational efficiency, thereby reducing the industry's environmental footprint. For instance, case studies from Maersk Line and the Port of Rotterdam demonstrate that despite challenges such as implementation costs, data security concerns and regulation, collaborative efforts and public–private partnerships including shipping companies, ports, technology providers, and regulatory bodies, can support efforts towards a more sustainable maritime industry (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). This signals that collaboration among diverse stakeholders within the maritime ecosystem is not only essential for overcoming the practical challenges of implementing AI technologies, but also fundamental to the systemic changes required for business model innovation towards a more sustainable industry.

Despite the proven potential of AI technologies, firms across different sectors still struggle with the question of how to use them to significantly improve business decision-making, productivity and product innovation (Babina, Fedyk, He, & Hodson, 2024), which inevitably involves redefining of the value proposition, value delivery, and value capture, enabled by digital technologies i.e. digital servitization (Chen, Visnjic, Parida, & Zhang, 2021). More importantly, such innovation is dependent on the collaborative efforts of different actors within an ecosystem (Kolagar, 2024).

2.6 Collaborative Value Co-Creation for Sustainable Business Model Innovation

The implementation of Sustainable Business Model Innovation (SBMI), as outlined in the previous sections, requires fundamental shifts in how companies operate, beyond traditional approaches like eco-innovations or efficiency gains to embed sustainability at the core of the business model. However, these changes are often too complex for a single firm to undertake in isolation. Therefore, collaboration emerges as a critical enabler for firms seeking to drive and implement corporate innovation for sustainability (Bocken, Short, Rana, & Evans, 2014).

The need for collaborative approaches in maritime SBMI stems from the complexity of the challenges facing the industry and the distributed nature of its operations (Fiksdahl & Wamstad, 2016). For instance, shipping companies cannot independently address emission reduction targets without collaboration with port and terminal operators for optimized arrival and departure procedures (González Chávez, et al., 2024), or with technology providers for AI-enabled optimization systems. Similarly, the data-driven innovation essential for AI-enabled solutions requires information sharing across multiple stakeholders (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

Central to the collaborative approach is the concept of ecosystem orchestration, which serves to align partners objectives into shared purposes by defining governance principles and ecosystem roles (Kolagar, Parida, & Sjödin, 2022). Orchestration is essential for coordinating complex interactions required for SBMI, ensuring that diverse stakeholders, from shipping companies and port authorities to technology providers and regulatory bodies, work toward common objectives while maintaining their individual competitive positions (González Chávez, et al., 2024). This alignment is principal for implementing new value propositions in business model innovation, but it is also a fundamental to pursuit sustainable industry development while considering the social, economic, and environmental pillars (Kolagar, 2024). Effective orchestration requires establishing governance structures that can manage the tension between collaboration and competition (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

The orchestration process enables the development of collaborative models, including peer-to-peer models, crowdsourcing, and open innovation, can enable rapid adoption of sustainable business ideas, potentially influencing production and consumption patterns globally (Bocken, Short, Rana, & Evans, 2014). In practice, a collaborative environment that ensures multifaceted collaboration between actors within an organization, as well as external actors, is critically important for implementing transformative initiatives like digital servitization (Kolagar, Parida, & Sjödin, 2022).

The potential of these collaborative ecosystems extends beyond simple resource sharing to encompass genuine value co-creation dynamics. This collaboration allows for combining actor knowledge, resources, and capabilities to create aggregated solutions and provides incentives for continuous learning from different partners. This enhanced integration with ecosystem partners leads to co-innovation and greater value for customers (Kolagar, Parida, & Sjödin, 2022). Since business model innovation often extends beyond dyadic relationships to comprise multiple actors within an ecosystem, resulting in value co-creation among providers, service delivery partners, and customers (Sjödin, Parida, Jovanovic, & Ivanka, 2019).

The success of initiatives as those mentioned in 2.5. depends on effective orchestration mechanisms that align diverse stakeholder interests, coordinate resource contributions, and manage the complex governance requirements of multi-party collaboration while achieving meaningful sustainability outcomes while maintaining and enhancing operational requirements.

2.7 Synthesis of Relevant Literature

As discussed in the previous sections, the extent of the relevant literature reviewed covers six key research domains: Business Model (Innovation), (Digital) Servitization, Sustainability, AI Technologies, Ecosystem Orchestration, and the Maritime / Shipping Industry. Figure 2.1 presents summary of the topics covered by these publications, clearly demonstrating that topics such as Business Model Innovation (BMI) and (Digital) Servitization are extensively covered, especially because Servitization entails a business model paradigm shift that leads to BMI (Chen, Visnjic, Parida, & Zhang, 2021), while the Digital dimensions is added to Servitization as this process is described as supported and running in parallel to Digitalization efforts within an organization (Chen, Visnjic, Parida, & Zhang, 2021). Similarly, the Sustainability topic is ample covered, particularly in connection to Business Model Innovation leading to concepts like Sustainable Business Model Innovation (SBMI), and due to the potential of Digital Servitization in driving Sustainability (Abdelkafi, Pero, Masi, & Capurso, 2022).

Source / Topic	Business Model (Innovation)	(Digital) Servitization	Ecosystem Orchestration	AI Technologies	Sustainability	Maritime / Shipping Industry
Abdelkafi et al. (2022)		■			■	
Babina et al. (2024)	■			■		
Bocken et al. (2014)	■				■	
Boons & Lüdeke-Freund (2013)	■				■	
Bressanelli et al. (2024)		■			■	
Chen et al. (2021)	■	■				
Costabile (2024)			■			
Di Vaio et al. (2020)	■			■	■	
Durlik et al. (2024)				■	■	■
Favoretto et al. (2022)		■				
Fiksdahl & Wamstad (2016)	■					■
González Chávez et al. (2024)		■			■	■
Gupta et al. (2020)			■			
Kolagar (2024)	■	■	■		■	
Kolagar et al. (2022)	■	■	■			
Lin & Huang (2013)			■			■
Matricano (2020)	■					
Shakeel et al. (2020)	■				■	
Sjödin et al. (2023)	■	■		■	■	
Sjödin et al. (2019)	■	■				
Sjödin et al. (2020)		■		■		
Sridhar & Jones (2013)					■	
Tijan et al. (2021)	■					■
Zechiel et al. (2024)				■	■	

Figure 2.1. Key Topics presence in relevant literature (Self - illustration)

Figure 2.2. visualizes these relationships through a chord diagram, where the outer ring segments represent the frequency of topic coverage by the literature, and the connection chords illustrate the inter-topic relationships. Here the strong connection between Business Model

Innovation, Digital Servitization, Sustainability is visible. As an emerging area of interest, AI technologies appears fairly represented, especially in connection to Sustainability due to its potential to address mounting environmental (Abdelkafi, Pero, Masi, & Capurso, 2022) and sometimes the related sustainability concerns of its use (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024).

On the other hand, the analysis also reveals opportunities for improvement in the literature. Ecosystem Orchestration for instance emerges as the least represented topic, as its connection to other topics is still underdeveloped. Most notably, the absence of connection to AI-technologies is evident as this rises the opportunity for future investigation on how AI can enable better coordination of complex business ecosystems such as the Maritime.

The Maritime-Shipping Industry shows moderate integration with all topics but the connections to AI technologies, Ecosystem Orchestration and Digital Servitization require strengthening through more foundational literature and their impact on Sustainability, which this research aims to address. Finally, as seen in figure 2.1., no single source covers all six topics simultaneously, signalling clear opportunities for comprehensive research in this domain.

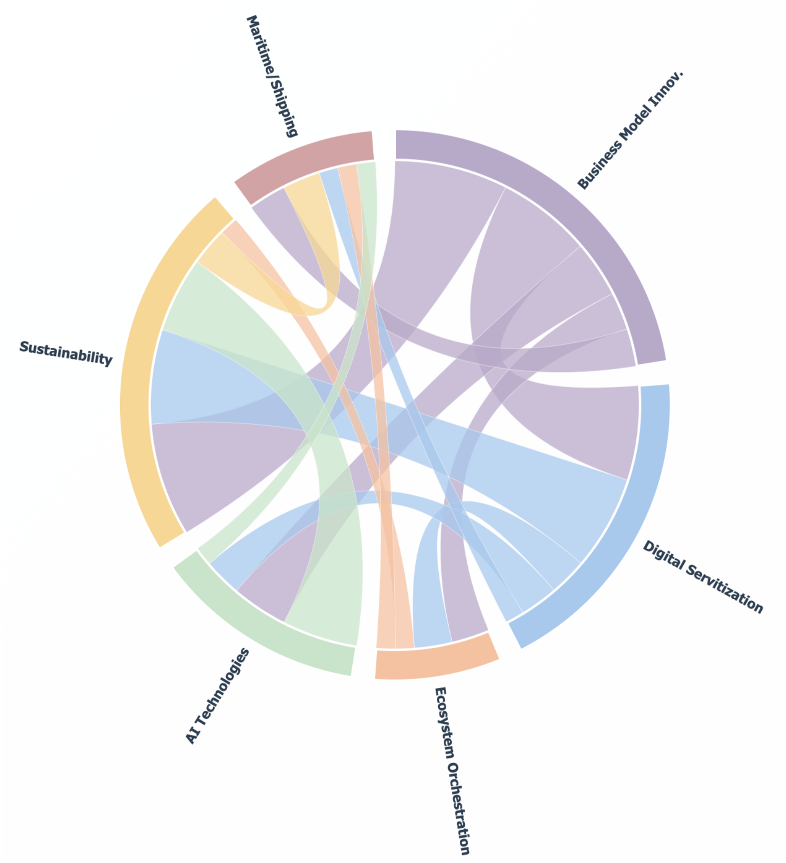

Figure 2.2. Representation of inter-topic connection of the literature (Self - illustration)

3 Methodology

In this chapter, a detailed description of the Research Approach, Methodology, Data Collection instruments and Data Analysis process is provided. The main objective of this study is to improve knowledge on a phenomenon in relation to sustainable business model innovation. As discussed in the literature review, this is an emerging field of study that requires the observations of contemporary events.

3.1 Research Philosophy and Approach

The decision to innovate is closely related to critical decision-making, to aid in this decision thorough research needs to be conducted. Sekaran & Bougie (2016) define research as an organized, systematic, data-based, critical, objective investigation into a specific topic to provide a solution. In this regard, a scientific approach should aid to find out the truth about a subject. Here, the prevalent research philosophical perspectives in business are positivism, constructionism, critical realism, and pragmatism (Sekaran & Bougie, 2016).

A relevant aspect of pragmatism is its focus on drawing from different points of view of the subject of study to solve the business problem and more importantly considers the definition of truth as provisional, therefore only tentative and changing over time (Sekaran & Bougie, 2016). Thus, suitable for the evolving nature of sustainable business model innovation.

Similarly, the nature of the AI phenomenon in current times is still novel and in development within the business applications field, for which little or no previous theory exists (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). This is very much in line with the description of Nascent Theory Research. As previously discussed, the impact of AI technologies within the shipping industry in strategic decision-making is still unknown, thus needing rich, detailed, and evocative data to bring more clarity to the topic, which lead to inductive theory development. (Edmondson & McManus, 2007). Induction, in this regard, is required to move from empirical observations about a phenomenon to the development of concepts and theories based on them, which is particularly relevant for young fields of study such as management (Woiceshyn & Daellenbach, 2018). Some other aspects relevant to the inductive approach are the 'use of data', which will be collected to explore a phenomenon, generate a theory in the form of a conceptual framework; and the form of 'generalisability', which in this case will be done from the specific (of the observations) to the general (Saunders, Lewis, & Thornhill, 2023).

3.2 Research Method Selection

Employing the definitions used by Saunders et al. (2023), the purpose of this research is best described as a combined study, considering the exploratory and evaluative dimensions of the study. This is further explained in more detail.

The purpose of this research is exploratory in nature, as it seeks to improve knowledge of a phenomenon not yet fully conceptualized in existing literature (Sekaran & Bougie, 2016), described as: sustainable business model innovation that leverages AI-driven technologies in the shipping ecosystem. This is also highlighted by the main research question and sub-questions, which start with "How" and "What" (Saunders, Lewis, & Thornhill, 2023), signalling open-ended investigation designed to surface patterns, perspectives, and potential relationships among different elements of the study.

Furthermore, the research also contains an evaluative component as it also tries to assess the sustainability benefits of AI-driven technologies, in other words, an evaluative study finds out 'how well something works' (Saunders, Lewis, & Thornhill, 2023). The expected outcomes include description of AI enabled benefits in terms of operational performance, sustainability, and economic value, but also how these benefits are perceived by different stakeholders within the ecosystem. More specifically, the objective is to understand the extent to which AI contributes to sustainable value creation in the industry.

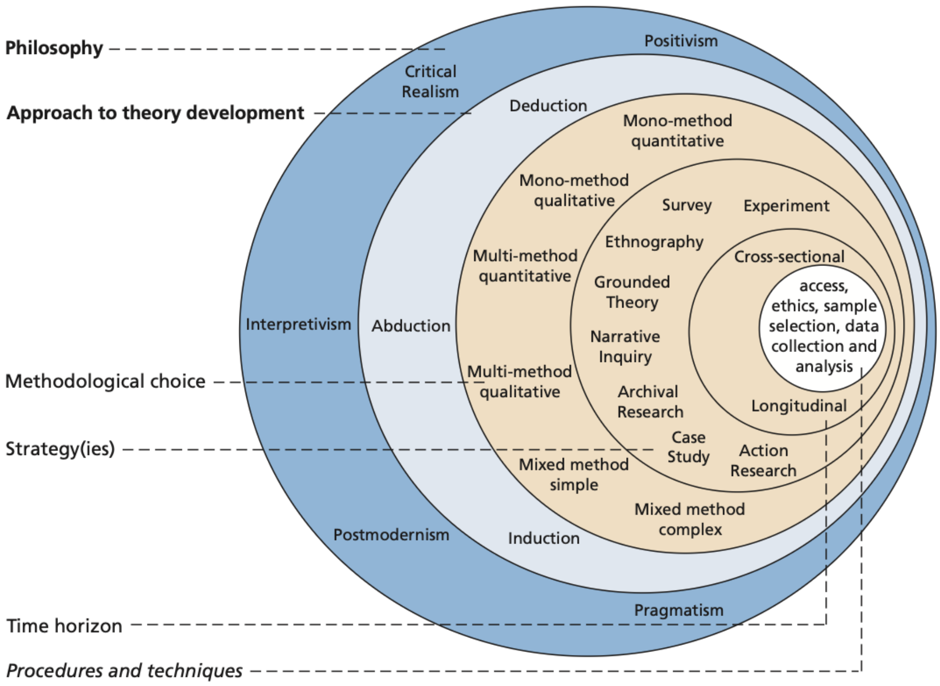

Figure 3.1. The research onion (Saunders, Lewis, & Thornhill, 2023)

Progressing with the model presented by Saunders et al. (2023) for research design in figure 3.1., the next step is to define the methodological choice. Exploratory research often relies on qualitative approaches to data gathering (Sekaran & Bougie, 2016) as it allows for comprehension of complex processes and identify theoretically new phenomena. This choice is further supported by the evaluation of methodological fit between the state of prior theory, research questions and research design to support a relevant contribution to scientific literature (Edmondson & McManus, 2007) as shown in figure 3.2. Furthermore, as this is an emerging field of study and the phenomena to explore is directly observable in contemporary events over which the investigator (myself) has no control, the literature-recommended research strategy is conducted through an exploratory single-case study (Yin, 2011).

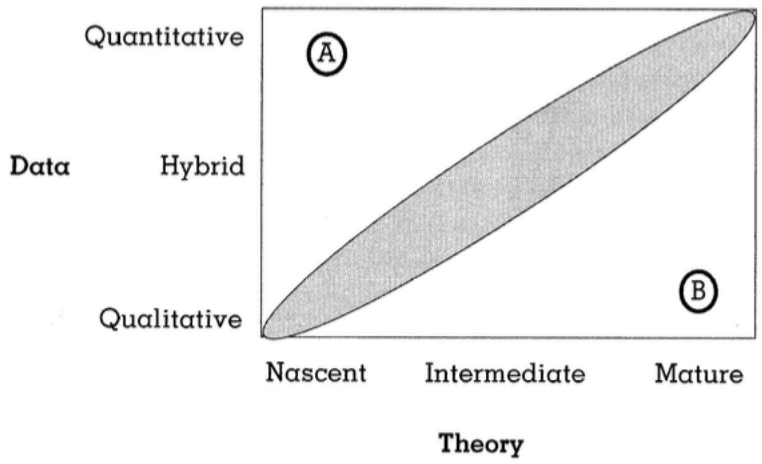

Figure 3.2. evaluation of methodological fit as a mean tendency (Edmondson & McManus, 2007)

Next the choice of research strategy is made, better described as the methodological link between philosophy, data collection and data analysis methods (Saunders, Lewis, & Thornhill, 2023).

To begin, as the research objective is to generate new theoretical understanding inductively from empirical data, rather than testing hypotheses, a suitable strategy for this purpose is grounded theory (Saunders, Lewis, & Thornhill, 2023). This supports the discovery of patterns, categories and relationships derived from understanding the process by which actors construct meaning out of intersubjective experience (Eisenhardt & Graebner, 2007).

Moreover, grounded theory provides a structured but adaptable methodology that aligns with the iterative nature of the research. Core activities during the development are coding, emergent theory comparison, categorisation, theoretical sampling (cases selection based on suitability for the study) until achieving theoretical saturation (i.e., when no additional data help develop new categories, thus further sampling is unnecessary (Saunders, et al., 2018; Chase & Murtha, 2019)) and leading to theoretical explanation (Saunders, Lewis, & Thornhill, 2023). More specifically, the strategy involves linking the data collected from this exploration with existing and emergent theory through a grounded theory approach. During this iterative process, theoretical categories emerge from evidence and shape further data collection (Edmondson & McManus, 2007).

Finally, grounded theory as an emergent strategy allows the researcher to maintain theoretical sensitivity, as described as the capacity to remain sensitive to meaning in the data and concepts emerging from it rather than using concepts in existing theory. This is particularly important in the coding but also in sampling decisions, as multiple perspectives can be analysed (Saunders, Lewis, & Thornhill, 2023). The resulting grounded theory should reflect the evolving relationships between the key concepts that emerge from the data, while linking these insights back to the participants' experiences and the empirical evidence (Gioia, Corley, & Hamilton, 2013).

As for the time horizon of the study, this is defined as cross-sectional, since the study involves collecting data of a particular phenomenon at a given point in time this is expected given the time constrain. Cross-sectional studies are still suitable for qualitative research (Saunders, Lewis, & Thornhill, 2023).

3.3 Data Collection Method

This research includes the following methods for data collection: literature review, semi-structured interviews, and desk research. The choice is further explained.

3.3.1 Relevant Literature Analysis

For the purpose of this study, the literature analysis serves to establish the necessary academic context and theoretical foundation of the research. It is relevant for clarification and deep understanding of core concepts of the research such as business models, business model innovation, AI-enabled innovation in the maritime industry, and relevant regulatory frameworks. Moreover, the review process was essential in defining the scope of the research, research questions and consequently the interview protocol.

Given the exploratory and evaluative nature of this study, a structured literature analysis was carried out to gather useful knowledge from both academic research and industry specific sources. The information collected through this review is presented in Chapter 2 and serves as a foundation of the interviews and analysis that follows.

Finally, as indicated by Sekaran & Bougie (2016), the purpose of unstructured interviews is to bring some preliminary issues to the surface and the interviewer should be able to listen carefully for important messages that might be conveyed in a very casual manner, thus foundational knowledge of the topics in discussion is necessary to establish the rapport and credibility necessary to motivate individuals to respond. Consequently, the literature review aided in interpreting new information collected through a theoretical lens.

3.3.2 Semi-structured Interviews

Following the recommendations for nascent theory, rich, detailed, and evocative data are needed to clarify and define on the phenomenon. Interviews and open-ended questions are among the methods for learning with an open mind. Openness to new input from the field ensures that the researcher identifies and investigates key variables over the course of the study (Edmondson & McManus, 2007). Therefore, the primary source of information will be semi-structured interviews with companies' representatives within the shipping ecosystem. More specifically, a thematic-format semi-structured interview protocol will be followed (Kolagar, 2024; Scholten, Pulles, Hazeleger, & Fenneman, 2024). In this approach, interviews are guided by a set of pre-defined themes and initial questions relevant to the study with the aim to answer the research questions while allowing for flexibility to explore emerging topics in more depth (Saunders, Lewis, & Thornhill, 2023).

Consistent with the qualitative approach, initially open-ended data need to be collected for further interpretation. A first source of information will be obtained from interviews (Edmondson & McManus, 2007) with project leaders and internal sponsors at the corresponding companies currently involved in the collaboration efforts within the shipping ecosystem. This interviewing process will start by selecting key informants who are directly involved in orchestration efforts and that can be of help to referral to other informants also working towards AI-driven solutions for sustainable innovation.

The structure of these interviews will follow a semi-structured protocol and the sample is path dependent meaning that subsequent interview questions and interviewees are determined iteratively as interesting ideas emerge in the process (Edmondson & McManus, 2007) including different topics such as AI-driven innovation, sustainability outlook, collaboration management and value co-creation.

3.3.3 Desk Research

The main purpose of this Desk Research was to accumulate secondary data from organizational reports, business journals, company documentation or other material from industry sites that can yield qualitative data relevant to the phenomena (Ellram & Tate, 2016). Understanding of the secondary sources will be validated with the corresponding subjects interviewed to avoid misinterpretation. This research also helps build a more precise knowledge of the current state of the business model in the shipping ecosystem and to investigate the phenomenon of analysis more completely (Ellram & Tate, 2016).

The data collection method per sub-research questions are summarized in table 3.1.

Table 3.1. data collection method per sub-research question

Sub-Research Question	Data Collection Method
What characterizes the current business models within the shipping ecosystem?	Literature review Semi-structured interviews Desk Research
How AI-driven technologies can impact value creation, capture and delivery in the shipping ecosystem?	Literature review Semi-structured interviews
What are the sustainability benefits of adopting AI-driven technologies?	Literature review Semi-structured interviews

3.4 Research Strategy Development

Keeping consistency with the recommended method for nascent theory development (Gioia, Corley, & Hamilton, 2013; Edmondson & McManus, 2007) this research adopts a thematic coding approach grounded in the Gioia methodology. This approach supports rigorous concept development that ensures transparency in how raw qualitative data is transformed into abstract theoretical insights. The specific process adheres to the following steps:

- In-depth analysis of the raw data: The interview transcripts will be read several times, highlighting phrases and passages related to the overarching research purpose of understanding how AI-enabled servitization supports sustainable business model innovation to establish first-order categories. The objective is to create 1st-order categories that try to adhere faithfully to informant terms.
- Next, a more interpretive role is assumed by identifying links and patterns within the first-order categories with support from literature on servitization, AI-driven innovation, sustainable innovation, ecosystem orchestration, and secondary sources. This process will lead to aggregation of first-order categories into second-order themes that represent theoretically distinct concepts. This should also help filter out redundant sub-themes and codes unrelated to the research objective.
- Next, these themes will be aggregated into dimensions that represented a higher level of abstraction in the coding. Also supported by the literature. A particular attention is made on nascent concepts that don’t seem to have an adequate theoretical referent or might stand out due to their relevant.
- The previous work is aggregated into a data structure, which is a visual and analytical representation of the coding process that help to make explicit the progression from empirical observation to theoretical abstraction.

- Finally, the dimensions, themes, and codes will be discussed and reviewed with knowledge experts (i.e., supervisors) to ensure findings are relevant to the research questions.

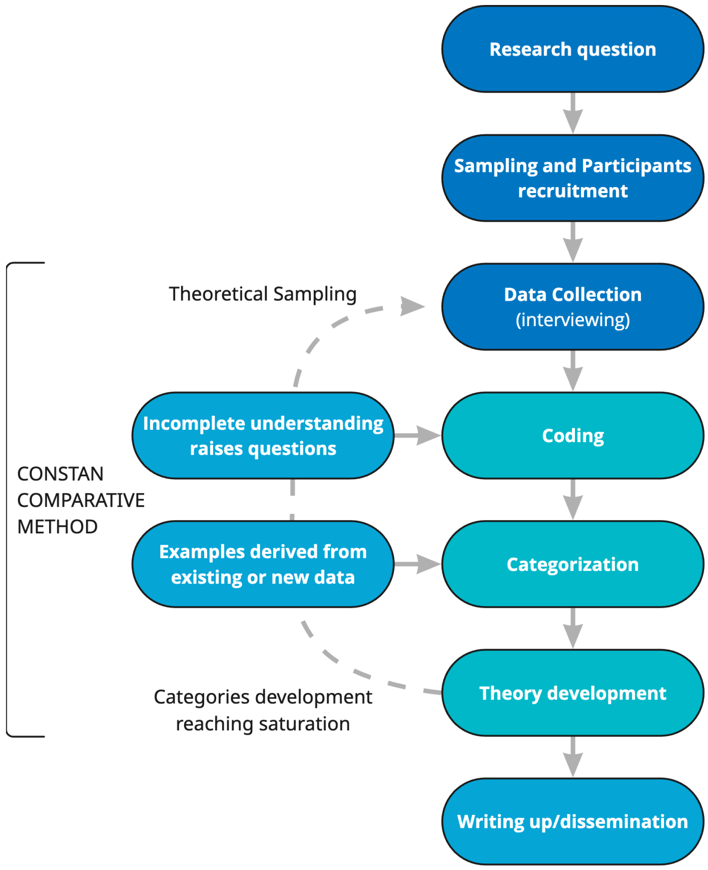

Figure 3.3. Representation of Grounded Theory Process based on Brunette (2022) (Self - illustration)

During the analysis process, iteration between the empirical data and theory is recommended for ensuring accurate and reliable theory generation (Edmondson & McManus, 2007). An inductive approach will be followed during the data analysis by examining and comparing the data, producing categories and constructs, and analysing the relationship among each other (Daly, 2007). This is depicted in the Grounded Theory Process adapted from the work of research design and core process presented by Brunette (2022) in figure 3.3.

Furthermore, to ensure robustness of the constructs, although thoroughly measures of external validity and reliability are difficult to produce for emerging fields of study (Edmondson & McManus, 2007), the most relevant factor to consider for construct formation is "category reliability" (Sekaran & Bougie, 2016). Thus, the outcome of the coding process will be reviewed with knowledge experts.

Because the phenomenon of interest is related to strategic decision-making, which is not an everyday activity, the data collected can introduce bias by "retrospective sensemaking" and "impression management". A recommended strategy to mitigate this effect is to interview informants who can describe the phenomena from diverse perspectives, which in this case will be handled by the inclusion of actors from different organization, hierarchy levels and departments (Eisenhardt & Graebner, 2007).

Additionally, in this context of qualitative research, validity refers to the extent to which results accurately represent the data (internal) and can be generalized to other contexts (external). Firstly, since information analysis solely supported on recall introduces researcher bias, aside from note taking, the responses will be recorded for in depth analysis (Sekaran & Bougie, 2016). Secondly, a recommended method to reduce researcher-bias and improve validity of the results is data triangulation (Sekaran & Bougie, 2016), which will be conducted by comparison of the research outcome with other studies in the field of servitization and sustainable business model innovation. Finally, cross-source validation will be executed by identifying discrepancies and complementary insights in an iterative manner to understand variations in interpretations between sources to ensure robust conclusions and the development of converging lines of inquiry (Yin, 2011).

3.5 Interviews

3.5.1 Interview Protocol Design

The interview protocol was systematically designed to align with the study's research objectives and sub-questions, ensuring comprehensive data collection across all dimensions of AI-driven sustainable business model innovation explored. As recommended by Saunders et al. (2023) the thematic format of the semi-structured interviews was constructed around the research questions using a list of pre-determined themes and initial questions to guide the interviews. Therefore, the core thematic areas used were: business models; AI-driven technologies impact on value creations, delivery and capture; sustainability benefits; and ecosystem collaboration dynamics.

For each thematic area, open-ended questions were formulated to encourage rich, detailed responses while avoiding leading questions that might bias participants toward particular perspectives (Saunders, Lewis, & Thornhill, 2023). The protocol included primary questions such as "How does your organization capture value from the products or services you provide?", "What motivates your organization to explore or implement AI solutions?" and "What external partners or collaborations do you consider most relevant for AI initiatives?". During the elaboration of questions, insights from digital servitization, business model innovation and applied AI literature were considered to ensure theoretical relevance while remaining accessible to practitioner with varying levels of technical expertise. The baseline interview protocol is presented in Appendix B.

The semi-structured interview approach was deliberately chosen to balance systematic data collection with the flexibility necessary for exploring emerging themes and following interesting lines of inquiry that arose during conversations (Edmondson & McManus, 2007). Also, the protocol was organized to explore views from actors around central topics rather than to answer a predefined set of questions. This allowed the conversation to adapt to different levels of expertise, responsibilities and organizational context (Saunders, Lewis, & Thornhill, 2023). This was particularly relevant since the interviewees belonged to roles from C-level executives to technical specialist.

As the study progressed, questions were refined to explore topics discussed in previous conversations and that could be further explored with other participants. Similarly, categories that emerged from the preliminary data analysis were also explored in future conversations. This was done deliberately to incorporate the 'emergent strategy' and 'theoretical sensitivity' features of the grounded theory approach. As described by Saunders et al. (2023), the 'emergent strategy' refers to let the research be guided by the data collected rather than by concepts in existing theory, while ‘theoretical sensitivity’ refers to the effort of focusing on interpreting meaning by using in vivo codes generated from the research rather than a priori codes (concepts) from the literature (Saunders, Lewis, & Thornhill, 2023).

Through refinement cycles the questions were slightly adjusted to incorporate preliminary findings but also to phrase concepts in line with the correspondent perspective of the role and organization of the interviewee, some examples are provided in table 3.2. This adaptive approach ensured that later interviews could explore newly identified themes while maintaining consistency with core research objectives (Gioia, Corley, & Hamilton, 2013).

Additionally, the informed consent process was designed to ensure ethical compliance as well as to support trust building and rapport with participants, recognizing that AI implementation decision represent part of the current strategic business landscape and could potentially include sensitive topics (Saunders, Lewis, & Thornhill, 2023). A comprehensive informed consent form was developed that clearly explained the purpose of the research, methodology, and intend of use of the findings, emphasizing the academic nature of the study and the anonymization measures to protect the participants and organization identities (Saunders, Lewis, & Thornhill, 2023). The consent also provided the opportunity for participants to review the content of the data gathered for analysis, ensuring their compliance with the information used. As judged by the results, this supported participants’ willingness to share specific examples of industry relevant topics as well as personal experiences.

Table 3.2. Iterations of protocol questions

Original question	**Adapted questions**
Could you share an example of an AI-related project or initiative that you think could fit within your organization?	Can you share examples of AI or ML applications where you’ve co-developed solutions with clients in maritime logistics?
	What types of AI applications do you think are most relevant for your maritime clients?
What are the main challenges or barriers you have experienced, or you think could affect the implementation of AI in your organization?	What are the main challenges when integrating AI into safety-critical or regulatory processes?
	What challenges have you encountered or anticipate when implementing AI-driven tools in the shipping context?
How does your organization create value in the shipping industry?	What are the key services or capabilities that differentiate your organization in terms of value creation for customers?
	In your view, what do your maritime customers value the most about your company’s services or products?

3.5.2 Sampling Criteria and Recruitment Process

The intended perspective of the study is that of a maritime-shipping ecosystem to understand the collaboration dimension of sustainable business model innovation; thus, the initial mapping deliberately targeted diverse stakeholder categories beyond only shipping companies. Furthermore, as described by Eisenhardt & Graebner (2007) some of the challenges with interview data is the bias introduced by impression management (influence projected image from the interviewee) and retrospective sensemaking (reflecting on past experiences) which is best mitigated by using numerous and highly knowledgeable informants who view the focal phenomena from diverse perspectives.

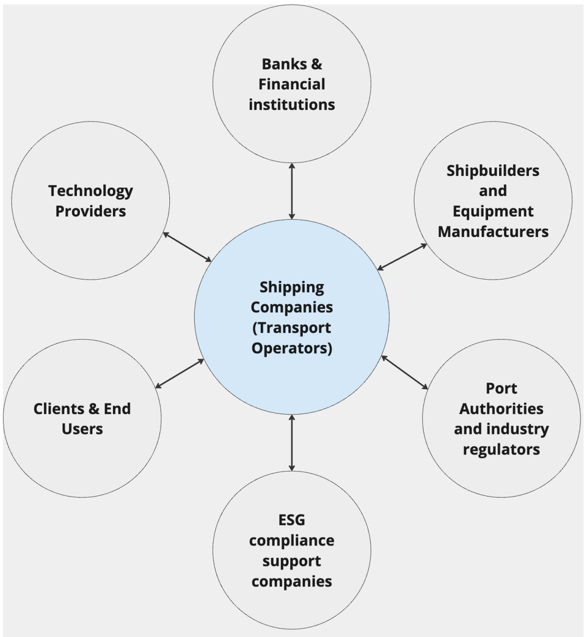

Figure 3.4. Initial ecosystem mapping (Self - illustration)

Initial mapping, illustrated in figure 3.4., identified 7 categories of stakeholder that could potentially be contacted: Shipping companies, Technology providers, Bank & Financial Institutions, Shipbuilders and Equipment Manufacturers, Port Authorities and industry regulators, ESG compliance support companies, Clients & End Users.

This approach ensured representation of different perspectives on AI adoption, sustainability challenges and collaborative innovation processes. Additionally, this helped to support and explore claims from single actors with respect to their external interactions.

The case selection strategy employed purposive sampling with specific criteria designed to identify organizations and individuals capable of providing rich insights into the core topics of AI-driven business model innovation and sustainability priorities with respect to maritime operations (Sekaran & Bougie, 2016). Organizations were selected based on the following criteria to support the reliability of the findings and therefore gain valuable insights:

- Demonstrated involvement or serious considerations of AI technologies adoption within maritime operations.
- Active engagement with sustainability objectives in their operating activities beyond basic regulatory compliance.
- Experience with digital transformations or innovation projects within the past two years.
- Operations presence within the Dutch maritime ecosystem with knowledge of local regulation and market conditions.

Table 3.3. List of companies interviewed, including description, industry, and roles

Company	Description	Industry	Role interviewed (# quantity)
Alpha	Maritime group specialized in dry bulk cargo across international trade routes. Focused on innovation and integrity in its operations.	Maritime Shipping – Dry Bulk	Chief Financial Officer (1), Chief Technology Officer (1), Business Optimisation Coordinator (1)
Beta	Shipping Company specialized in liquid bulk cargo across the globe with a strong focus on safety, environment and customer satisfaction.	Maritime Shipping – Liquid Bulk	Commercial Director (1), Services Manager (1)
Gamma	Organization in charge of managing port operations that supports global trade.	Port Management	Data & Tech Lead (1), Programme manager (1)
Delta	Company specialized in the maintenance and repair of marine engines and chargers.	Marine Equipment Maintenance	Chief Financial Officer (1)
Epsilon	Supplier of marine engines, maintenance services, and technical support.	Marine Equipment Maintenance	Data & Tech Manager (1)
Zeta	Startup in maritime innovation, specialized in vessel operations automation and human-machine interfaces	Maritime Technology	Co-founder / Chief Financial Officer (1)
Omicron	Offshore contractor specialized in engineering and logistics of marine infrastructure projects through the operation of heavy-lift vessels.	Offshore Engineering	Development Lead (1)
Theta	Organization involved in collaborative research and innovation focused on applying artificial intelligence technologies within port and maritime operations.	Maritime AI Research & Innovation	Innovation Manager (1)
Iota	Governmental agency responsible for maintenance and regulation of inland waterways, supporting commercial shipping and logistics.	Infrastructure Management	Modelling Specialist (1)
Kappa	Provider of an AI-driven digital platform that supports organizations in managing their ESG performance.	ESG Technology & Consultancy	Account Executive (1)
Lambda	IT services provider specialized in guiding organizations through digital transformation, including AI, and committed to achieve a positive impact in society.	IT Services & Consultancy	Head of Alliances (1), Data Consultant (2), CSRD Manager (1), Data Scientist (1), Unit Manager (1)
Sigma	Financial institution offers financing for shipping companies, port infrastructure projects, and sustainable technology investments.	Financial Services	Tech Lead (1)
Omega	Electronics manufacturer with a focus on minimizing environmental impact across its supply chain.	Electronics Manufacturing	Sustainable Value Chain Lead (1)

Auxiliary selection criteria to ensure diversity of responses were the selection of organizations with different company size, ranging from startups to established multinational corporations. Also, different hierarchical levels of the organization were targeted, from technical experienced personnel to c-level executives. More specifically, judgment sampling guided the choice of subjects who were identified as most advantageously placed to provide the information required (Sekaran & Bougie, 2016).

The recruitment strategy employed multiple channels and networks to ensure comprehensive representation across the ecosystem (Saunders, Lewis, & Thornhill, 2023). Initial recruitment began through the sponsoring organization's network of clients and industry partnerships, leveraging their established relationships within the maritime sector. The researcher independently also contacted academic networks, which also provided an alternative to make connections through maritime research groups and collaborations networks, facilitating access to industry professionals engaged in digital servitization initiatives. Another method for recruitment used was the attendance to conference networks of applied AI technologies, where face-to-face interactions could provide opportunities to establish rapport and explain the research purpose in more detail. Social media was use through the employment of LinkedIn to identify and contact potential participants, and more importantly to validate their adequacy for taking part in the research. The multichannel approach was essential to overcoming communication barriers and the potential resistance to external engagement (Saunders, Lewis, & Thornhill, 2023) and as indicated by Eisenhardt & Graebner (2007), it reduces the chance of informants engaging in convergent 'retrospective sensemaking' or 'impression management'.

Similarly, the recruitment process benefited from cascade effects, where initial participants provided referrals to other relevant organizations and profiles within their professional networks, commonly employed when contacting members of the desired population is challenging (Saunders, Lewis, & Thornhill, 2023). This snowball sampling approach proved particularly valuable in the maritime industry, where trust and personal relationships play a crucial role in business interactions. This cascade effect also operated vertically within organizations, allowing access to people in different departments or hierarchical levels. As of the 22nd interview the study reached the data saturation point, as new interviews produce similar findings to those of previously gathered data with some elements also found in secondary data (Saunders, et al., 2018).

In the end, a total of 13 organizations were interviewed which serve different roles in the ecosystem, the list is summarized in table 3.3., including shipping companies from the bulk carrier segment (dry and liquid), which represents over 70% of the type of world fleet capacity by 2024 (Appendix C). Additionally, the conversion rate of people interviewed in comparison to those contacted was 56% with a total of 39 professionals contacted and 22 interviewed over the span of time of 2.5 months. This is relatively high conversion rate supports the recruitment strategy selected. The complete list of roles interviewed is summarized in table 3.3.

The interview sample also demonstrates strong diversity across different dimensions. For instance, as shown in figure 3.5., interviewees come from different hierarchical levels showing strong representation (27%) of C-level executives in strategic decision-making positions with authority over investment decisions such as AI; Senior Management positions is also fairly represented (14%), and these are professionals who bridge strategic decisions with operational activities. On levels closer to the operation, also Department Heads where considerably represented (27%), which bring a strong perspective on managing implementations projects, and Specialist (32%), who represent technical experts with experience on AI and IT implementation projects, as well as sustainability challenges. This distribution captures perspective from both strategic and operational levels, providing sufficient understanding of business model innovation dynamics.

Similarly, organizations from different sizes were contacted. The distribution in figure 3.5. shows that a great percentage (41%) belong to large organizations as well as very large (9%), which represent established players with enough resources for innovation and infrastructure. Nevertheless, Medium (32%) and Small (18%) sizes were also included, this group comprises technology developers, knowledge organizations with agile and innovation focused cultures, as well as operational players facing transformation requirements. This demonstrates coverage of a broad spectrum of organizational contexts where AI adoption perspectives might vary considerably. The detailed list can be reviewed in Appendix H.

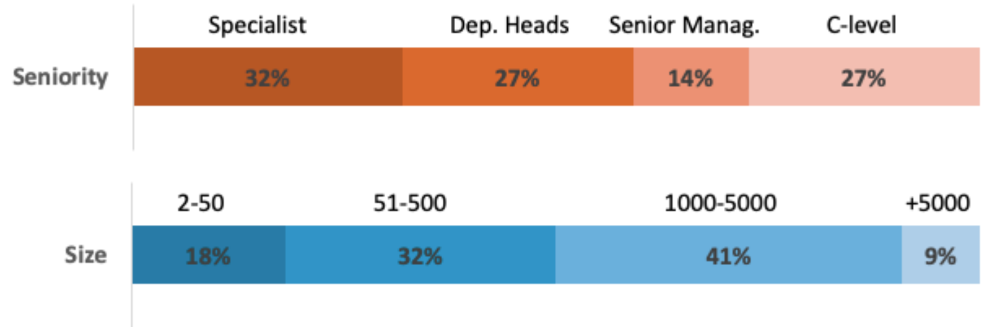

Figure 3.5. Interviewees distribution per Seniority and Organization Size (Self - illustration)

4 Results and Discussion

Following analysis of the data collected through the semi-structured interviews, it was determined that for the implementation of AI technologies happens in layers, starting with the assessment of the current capabilities of the incumbent business model. On a second level, the application and collaboration necessary for its adoption drive business model innovation in its three components in an iterative and collaborative manner through value co-creation, value co-delivery and value co-capture. Finally, the realization of the benefits at the social, environmental and economic levels is tightly linked to careful evaluation and development of the previous steps, taking into account the inherit trade-offs in corporate sustainability.

The findings thus are presented in five parts, including the steps necessary for their completion. First, a conceptualization and description of how to conduct Current Business Model Assessment and Technology Readiness is provided. Second, the stages to achieve business model innovation through AI adoption and key stakeholders' involvement are explained on the Value Co-creation, Value Co-delivery and Value Co-capture levels. Lastly, the influence of economic, social and environmental benefits and their interrelation are explained in Sustainability benefits realization. The complete coding tree including quotations is presented in Appendix E. Following the order of Aggregate dimensions and Second-order themes as presented in the data structure (see figure 4.1.), the relevant findings of the research are presented.

4.1 Current Business Model Assessment and Technology Readiness

This dimension encompasses the foundation evaluation and diagnosis phase that allows shipping companies to understand their position and readiness for embarking on sustainable business model innovation driven by AI-technologies. This dimension emerges from the recognition that incumbent market players are characterized by pressure-driven adoption attitudes with a strong focus on ROI (return on investment). Moving forward with AI implementation efforts, this should support informed decision-making about investments while minimizing operational disruption.

The dimension focuses on critical topics discussed during the interviews with 13 different organizations and draws insights from conversations with decision makers from shipping operators, operations support, IT services providers, and other ecosystem players to build up to a holistic view of unique requirements and constraints of the maritime-shipping industry.

This assessment acknowledges that successful implementation and adoption in the maritime context requires careful evaluation of legacy infrastructure, organizational capabilities, market positioning and sustainability priorities. Moreover, contrary to technology-first approaches, this dimension prioritizes the preparation of the organization for adoption of technologies that ensures operational continuity and risk mitigation, critical factors for companies that operate under financial pressure and are unable to afford operational disruptions during digital transformation.

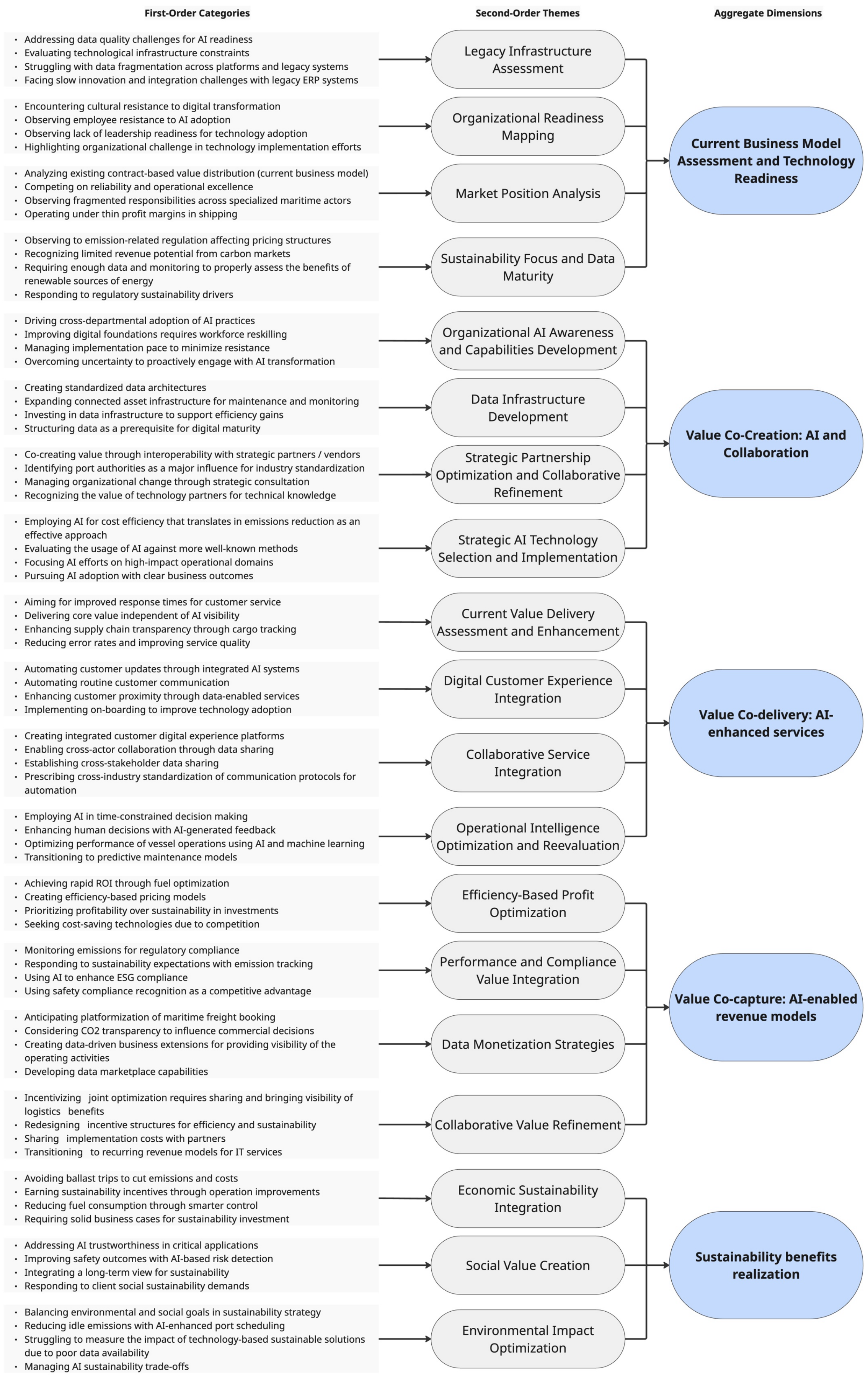

Figure 4.1. Data structure and coding process (Self - illustration)

4.1.1 Legacy Infrastructure Assessment

As part of the initial assessment, it was highlighted during the conversations that there exist critical constraints in initial technical capabilities and compatibility across systems. This step focuses then on a thorough analysis of the existing capabilities of the company that will adopt the technology. To begin with, as highlighted by *Evaluating technological infrastructure constraints*, the nature of the operation inherently implies the usage of legacy infrastructure across long periods of time, as stated by a data consultant from Lambda with experience working with the maritime industry:

"that shipping industry is kind of old-fashioned because you are creating, you are building a ship and the ship is at sea for 30 years […] it's not always built for modern data. For example, […] if you are talking about emissions, you want to know the fuel consumption, but for all the ships you are just looking in the fuel tank and say: oh, it's a halfway so we have so much metric tunnel fuel. […] That's also a challenge for the shipping industry."

This step was derived from specific first-order categories that made explicit limitations on the existing infrastructure, but also in the capabilities of the solutions that support the operation. For instance, *Facing slow innovation and integration challenges with legacy ERP systems* and *Struggling with data fragmentation across platforms and legacy systems*, further convey the fact existing ERP solutions are sometimes rather a limitation when trying to move to more advanced techniques of data usage and integrating data from these sources pose a major challenge, requiring special dedication. Mentions to the ERP (Enterprise Resource Planning) indicate the tension between the requirement for operational continuity and the need for technological advancements.

However, understanding the current infrastructure is key to be able to use the foundation of AI solutions, which is data. Thus, *Evaluating data infrastructure readiness* further emphasizes the relevance of data as a raw asset to be used in data-driven solutions and advanced analysis techniques, reflecting why shipping companies need to understand their current technical constraints before carrying out AI initiatives. As another senior data consultant from Lambda when discussing the challenges of implementing AI in maritime stated:

"challenges are data quality, data accessibility, data availability. […] it's very much related to the state of the data. I think those are really important issues."

Moreover, this step is relevant because it underscores the necessity of establishing realistic boundaries for AI implementation based on the existing technical constraints. For adopters, understanding legacy systems limitations prevents overestimating the potential of the new technologies and defining a clear starting point for the development of new capabilities. This assessment allows informed decision-making about the posterior technical steps and strategies such as integrations with existing systems, modernization requirements, or the adoption of complementary solutions to help close the technological gap.

This step belongs in the current business model assessment dimensions because it supports the evaluation of existing technical capabilities before jumping directly to future implementation proposals. This also ensures that the adopter develops a baseline understanding before risking themselves into technological changes that disrupt the continuity of their operations. With this information, realistic timelines and investment requirements affecting the following steps can be developed, ensuring that implementation efforts deeply understand operational constraints.

4.1.2 Organizational Readiness Mapping

An often-discussed theme during the interviews was the structural readiness of the organization to adopt technologies. Some of the first-order categories mentioned are *Acknowledging cultural resistance in AI adoption* and *Overcoming internal resistance to AI-based change*. These categories reveal insights into human resources and organization challenges that shipping companies and organizations part of the ecosystem in general face when considering AI adoption.

An interesting insight derived from various conversations was the introduction of the topic of an ERP migration process and its parallel with developing AI capabilities. This is exemplified in the following quote from the CFO of one of the shipping operators, Alpha:

"the main challenge is to explain and educate people. We are in the industry, but also we are a company that has to explain and educate people. […] we really had to catch up on that and get our act together that deals with transactional systems and the ERP implementation, but it also deals with data availability, data management data, more data-driven way of working."

This theme addresses the human dimension of AI implementation, recognizing that technological success depends fundamentally on organizational readiness, the first-order category *Encountering cultural resistance to digital transformation*, underscores the fact that shipping companies are already grappling with workforce age and transition challenges. Furthermore, *Observing employee resistance to AI adoption*, suggests that AI adoption must be carefully managed to avoid worsening existing human resource constraints and collaboration.

To further highlight the extension of the situation it was pointed out by *Observing lack of leadership readiness for technology adoption* that this is not an issue limited to purely operations related personnel but also at higher levels of the organization, as indicated by CTO of Alpha when asked about what is necessary for effective organizational change:

"But adoption and the disruption in the company itself is the biggest challenge I think. […] Because if your management is not up to the latest standards of technology, which is not common in our industry, then you have an issue."

What is more, this is not an isolated problem only certain service providers experiment, but a systemic form of operating within the industry, *Evaluating industry-wide organizational change resistance*. Thus, further exacerbated by the interaction with other ecosystem players, as expressed by the Data & Tech Lead of Gamma:

"the industry is widely recognized as one of the most traditional ones, so we see that when we try to digitalize operations with our customers we face a lot of resistance to shift from the ways you manage your operations for years and years"

Therefore, despite technical solutions availability and feasibility for implementation routes, organizational decision-making structures may not be equipped to sustain AI transformation effectively. As a result, understanding leadership readiness, workforce concerns and ecosystem dynamics supports the design of effective change management strategies that ensure operational stability while developing AI capabilities.

This theme falls under the evaluation of the current business model because it assesses existing organizational structures and culture readiness before implementing training programs or on-boarding processes that are blind to impactful barriers for innovation processes. This foundation serves as an appropriate input for the upcoming capability-building activities that are part of implementation stages.

4.1.3 Market Position Analysis

As part of the analysis, it was also relevant to understand the characteristics of the operation of shipping companies and those supporting their operations, the results reflect the nature of the industry in which the simultaneous collaboration and coordination across different organizations is key for delivering the product, not only supported by machinery and people but also by a continuous exchange of data.

Maritime-shipping organizations operate in diverse business models, from *Serving underserved market niches* to *Managing complex multi-cargo operational models* each representing different opportunities and constraints for AI integration. Moreover, there are *Contrasting operational models in maritime management*, for instance, owners of a vessel are not necessary in charge of management of the operation, in some scenarios an owner may rent them out to an operator or charter them out for a fixed period that can go up to 5 years. In addition, multiple layers of the operation can be outsourced, such as crew recruitment, safety management, technical management, environmental compliance and commercial operations, among others. This can further increase the complexity of producing and accessing the data integration necessary for the use of AI applications.

This theme acknowledges that AI implementation must align with existing business model strengths and market positioning strategies, as well as the importance of considering the structure of the operational mechanisms, particularly if access to data is of importance, as highlighted by seasoned implementation consultant of Lambda:

"In general, shipping companies own the vessels, make sure that there is some cargo on board and that they sail to A to B. […] but a lot of stuff is outsourced to companies that specialized it. […] also […] to collect data. So a lot […] is done together with other parties"

Their capacity for complex organization of their operation also demonstrates that these organizations actively compare their operational approaches with industry alternatives, which underscores their sophisticated understanding of market dynamics and competitive positioning.

Moreover, many of maritime operators depend on providing trustworthy services to their customers, as highlighted by the first-order category *Competing on reliability and operational excellence*. However, this also implies fierce competition in an environment in which operational continuity is a priority consequently proven business cases and operational benefits are a must before investment or long-term commitment, as expressed by the Head of Alliances of Lambda about their relationship with the maritime industry:

"I think that especially in this area, transporting and logistics, they're always looking at where can I save money? Because the margins are very thin. I think because of that, they are open to any technology that can help them to save more money or to get a higher margin."

Therefore, understanding current market positioning supports the identification of AI applications that strengthen existing value propositions and new revenue streams discovery.

Furthermore, the analysis ensures that AI investments target key market characteristics and competitive needs. Rather than developing new market strategies, this assessment provides the foundation for the development of value propositions aligned with the organization and the ecosystem it is part of.

4.1.4 Sustainability Focus and Data Maturity

Continuing with the assessment of the characteristics of the incumbent business model, it was also relevant to understand sustainability areas of priority as well as its relevance for the organization. As the first-order category highlights *Responding to regulatory sustainability drivers*, initiatives of direct industry players are mainly driven by regulation and pressure to comply. Thus, a potential for automation of regulatory compliance processes is observed.

Moreover, although some avenues for immediate valorisation of sustainable practices, such as the trading of emission allowances from EU-ETS are provided, this represents little incentive in itself to drive major change by *Recognizing limited revenue potential from carbon markets*, when consulted about the potential of monetizing increased environmental performance the business optimisation coordinator of Alpha expressed:

"A new business line? No, like, of course you have ETS, but the let's say the margins for selling the ETS, they are too low for us and also therefore not interesting to invest more in"

The enforcement of these mechanisms results in the transfer of the implementation costs to customers, as the services manager of Beta expressed:

"Ships trading in Europe, if you carry your products on the same distance in Europe or the same distance outside Europe, it will have a different transport cost in these. If there are customers looking to use some marketing or so they could use it. And obviously we're open for that time to use a more environmentally type of fuel if they're willing to pay for it."

However, this is not an ideal outcome for an industry that operates under premises of cost efficiency.

On the other hand, results also show proactive approaches, with some organization even *Structuring sustainability efforts around circularity and decarbonization*. And industry operators shared their experiences with ventures in technologies that employ renewable energies with a potential for emissions reductions. Nevertheless, a topic mentioned alongside was the discussion of limited data and infrastructure necessary to measure their impact. As pointed out by the CTO of one of the shipping operators, Alpha:

"So we need data to check it as well, because let's say for some vessels that were in the ocean, they were saving fuel, but on other vessels that were operating […] they didn't save anything at all. But you need to use data or machine learning at some point as well to get that proof and evidence right in based on data if it works or not."

This theme highlights the importance of aligning value propositions with environmental and strategic goals, while recognizing the need for adequate supporting infrastructure. For companies adopting new technologies and responsible practices, this assessment helps prioritize areas where AI can deliver meaningful impact. This also prevents setting goals that cannot be measured or validated with current capabilities, supporting the development of a more informed and actionable strategy, and set the stage for future improvement.

4.2 Value Co-creation: AI and Collaboration

This dimension emerges from the topics discussed during the interviews as a response to previous foundational analysis pointing out the strategic and operational transformational steps that support the development of AI capabilities within shipping companies and organizations involved through practical implementation and collaborative partnerships. As such, the co-creation property arises from the recognitions that maritime companies require ecosystem-orchestrated approaches from varied dimensions and compositions for the adoption of AI technologies, leveraging external expertise while building internal capabilities that build on rather than replace existing industry-specific knowledge.

During the discussions, various decision makers emphasized the necessity of partnerships-supported ideation, development and implementations of such technologies. Such collaborations often involve the development of critical capabilities within the shipping operators supported by technology providers, customers, service providers and ecosystem partners, such as port authorities. Therefore, recognizing that successful adoption requires coordinated efforts across multiple stakeholders while maintaining operations control and expertise within the organization.

Furthermore, the transformation requires that a strategic technology selection is made, robust data infrastructure is developed, and improved collaboration agreements are in place. In contrast to technology-first approaches, a human-centric AI development is required to improve operational expertise while securing ongoing operations and sustainable growth.

4.2.1 Organizational AI Awareness and Capabilities Development

The necessity of building foundational AI capabilities emerged as a critical theme across interviews, underscoring the need for comprehensive organisational preparation that goes beyond technical readiness. More specifically, topics often discussed are the development of AI literacy within the organization and change management efforts, recognising that for successful adoption both awareness development and structured organization transformation are required.

The conversations highlighted that *Building foundational awareness for AI implementation* entails more than just basic training, it involves developing comprehensive understanding of the technology's potential within the maritime operational context and ultimately *Improving digital foundations requires workforce reskilling*. Furthermore, *Driving cross-departmental adoption of AI practices*; thus, support from management is essential during this journey, as pointed out by a c-level manager of Alpha:

"So that's I think the greatest challenge to then also basically get your management behind this, that they understand it, that also the people in the commercial department understand they have to develop this way and keep their eyes open in the technical department, in the accounting department. So it's really changing the organization towards, yeah, a new way of more data-driven and AI driven working."

And even though this seems quite straight-forward thinking, in reality, many people involved in implementation efforts find themselves *Struggling with limited organizational resources from shipping companies when developing solutions*, this with regard to organizations not making appropriate time for the new knowledge so sink in or not getting enough people involved in this task. Thus, *Building internal data governance capabilities for shipping* *companies* comprises having dedicated roles for support and guidance, as better expressed by an implementation expert at Lambda:

"they have to hire in person internally. That's especially have is thinking about data, how to work with data, how to improve the data that is not a distracted with all the company stuff. And then you can do I think interesting stuff. […] If you have one person focused on how to work with data […]. Then you can make better sailing routes for ships. You can optimize maybe how many cargo you're loading […]"

This theme addresses the human dimension of AI adoption, recognizing that shipping companies face unique organizational challenges due to the industry's "traditional" or "conservative" culture (Appendix G). In the words of a technology expert from Alpha, one of the shipping companies interviewed:

"the organizational change and guiding that is half the task. It's half the workload for sure, and maybe more than half. […] adoption and the disruption in the company itself is the biggest challenge I think."

One of the reasons to emphasize this point is that, once people in the organization are engaged, developing the so-called business cases that align the industry's needs becomes more feasible, as highlighted by the first-order category: *Overcoming uncertainty to proactively engage with AI transformation*. More importantly, ensuring internal support for these adoption efforts contributes to "smooth sailing" during implementation, during a reflection on past AI implementations a consultant from Lambda expressed:

"if you try to do too brutally too quickly, then people will feel threatened. That's why this is a risk. I see the risk that people will instead of collaborating, they will actively try to stall it. Or that's what we saw at some organizations. So I think you have to frame it. For some people it's a big change, so that's a risk."

Thus, *Prioritizing organizational change management* and *Managing implementation pace to minimize resistance* emphasize the requirement to carefully manage the transformational process and staying aware of the maritime industry culture while building AI capabilities.

This theme belongs in the value co-creation dimension because, as it will further be emphasized, this process can only be realized through collaboration among internal stakeholders, technology partners and ecosystems actors. Emphasizing awareness building and change management is intended to support engagement, ensuring more effective collaborative AI development that aligns with operational requirements.

4.2.2 Strategic AI Technology Selection and Implementation

The strategic selection and further development of AI technologies emerged as part of the decision-making process that requires a deep understanding of operational requirements, potential opportunities and feasibility of implementation both in terms of internal capabilities and budget. Here it was often emphasized that AI application should preferably enhance human expertise and operational benefits while delivering measurable benefits, particularly emphasizing the importance of ROI.

Pursuing AI adoption with clear business outcomes, is expressed in terms of mainly securing profit for the company, which could be achieved for instance through higher efficacy or cost reductions. What remains relevant for operating actors is *Adopting AI to optimize business processes*, namely, to drive efficiency while reducing the risk of affecting on-going operations.

The conversations revealed that *Prioritizing value-generating initiatives* and *Focusing AI efforts on high-impact operational domains* represent a crucial strategic approach for operational adopters. Rather than pursuing the adoption of new technologies for the sheer novelty, companies aim to identify specific operations areas where AI can deliver measurable but also feasible value. These insights extend further than only shipping operators, as also those organizations supporting their operations share similar views, underscoring the importance of collaborative value development. As expressed by the CFO of Delta:

"The simple answer would be is a for profit company. So the simple answer would be to increase efficiency, reduce costs. I would definitely say that those are the two main key drivers […] we don't want to digitize just because of digitization. The purpose would be to become a better positioned, profitable company in the future."

In this regard, a particular insight emerged around the multiple benefits of such implementations, as expressed by *Employing AI for cost efficiency that translates in emissions reduction as an effective approach*, referring to any solution that focuses on improving vessel or voyage performance ultimately translating into a reduction in fuel consumption, thus costs and emissions reduction.

It is important however, as it was also discussed, to remain critical in this stage by *Evaluating the usage of AI against more well-known methods* while *Targeting specific operational pain points*. This suggests a pragmatic approach to the adoption of any technology, focusing on specific challenges rather than broad transformation initiatives.

Nevertheless, conversations underscored the importance of *Seeking clearer business cases to drive AI investment* as part of the exploratory nature of implementation efforts, requiring clear value propositions and ROI before committing to more elaborate developments. As expressed by the financial head of Alpha on pursuing relevant use cases for AI:

"As a shipping company, if we would get better use cases for ourselves. And sometimes it's coming through more complicated systems like we're doing now on voyage optimization, but there must be more and more use cases coming up."

Technology selection surfaces as a collaborative process involving strategic partnerships between shipping operators, service support companies, technology providers, specialized consultancy and innovation organizations. These partnerships create a shared learning environment where feedback from pilot projects continuously refine technology selection priorities and inform data infrastructure requirements. This theme is included in the value co-creation dimension because it reflects on the collaborative nature of AI technologies selection, implementation and adoption as part of sustainable business model innovation.

4.2.3 Data Infrastructure Development

The development of robust data infrastructure arises as a fundamental prerequisite for implementing or even presume to adopt any kind of AI-driven technology, which represents a technical challenge as much as a strategic opportunity. This theme reflects on the creation of the data foundation that necessarily involves careful balancing of legacy systems constraints with modernization requirements through planning and capability development.

To begin with, development of the infrastructure requires conducting a proper assessment of the systems at hand and defining the direction of upcoming tasks. Or as summarized by *Structuring data as a prerequisite for digital maturity*, the innovation lead of Theta stated:

"smaller companies first need to get their data house in order, so they are usually not that structured actually. […] I think in the smaller companies mainly use the main thing is planning, so I think planning is the most usually the most important parts."

A clear sign of maturity in an organization was mentioned being able of *Creating standardized data architectures*, this refers to the establishment of some sort of corporate data model the reflects the data reality of the company, but that is also able to integrate with data coming from and intended to external partners.

Furthermore, the conversations reflected on identifying areas in more need for improvement such as *Modernizing legacy system architectures* as well as spotting opportunities brought up by other technology advancements and *Overcoming historical internet connectivity limitations opens up new technology markets*, which refers to the ongoing adoption of low-orbit satellite technology which also support the adoption of AI.

Given the nature of the operations emphasis is made on *Implementing automated data collection systems*, to capture data generated by the vessel, performance influencing factor and key logistic processes. For instance, marine equipment maintenance providers aim at *Expanding connected asset infrastructure for maintenance and monitoring* to offer better support and ensure client's uninterrupted operation. In this regard, the tech lead of Epsilon indicated the next goal as part of their efforts to provide better customer service:

"we mainly want to increase the number of connected assets […] because it gives us more opportunity to analyze data to help customers remotely. We're working on that as a priority"

As often mentioned, this effort in itself should already provide a direct operational benefit, thus *Investing in data infrastructure to support efficiency gains*, as expressed by Beta, confirms that operational adopters view this technical work as a strategic investment for improved performance. The value can emerge through process optimization and integration capabilities by *Streamlining processes through integrated data systems*, for example by reducing the need for manual input, improving data quality and providing a holistic view of the operation.

Similarly, it was further discussed that technical developments should be coupled with *Building internal data analytics capabilities*. In this regard, it was observed that companies usually turn to specialized providers to support with this knowledge development to derive value from their data investments and overtime become able to reduce dependency on external providers.

Additionally, a specific reason for development of data infrastructure was often mentioned around the topic of sustainability, which involves the appropriate measurement and monitoring for compliance and optimization. Moreover, in reference to previous experiences with technologies adoption some interviewees reported *Observing implementation of sustainability technologies without mechanisms to measure long-term impact*, emphasising the importance of measurement mechanisms to justify investments, especially when made pursuing environmental and efficiency improvements.

The emphasis on systematic planning, standardized architectures and integrated capabilities supports ecosystem-wide collaboration and establishment of partnerships based on data sharing and systems integration. Among other benefit, these developments should further improve operational control and competitive advantage, but more importantly serve as the basis for co-development of advanced data-driven solutions such as AI applications.

4.2.4 Strategic Partnership Optimization and Collaborative Refinement

Leveraging strategic partnerships surfaced as a critical requirement for operational adopters who simply lack internal resources for comprehensive AI adoption. The theme focuses on the establishment of collaborative relationships that enable shipping companies to access crucial capabilities while maintaining operational focus and autonomy.

As a starting point, on the side of a shipping company one interviewee mentioned *Relying on external expertise to drive AI integration*, referring to the lack of internal capacities to carry out these endeavours on their own. Additionally, on the side of specialized consultancy services it was also mentioned that *Engaging tech partners to support AI implementation* was also relevant to select the best technological fit for every project. This reflects a path on the complex line of collaboration necessary.

Another relevant aspect is the particularly complex ecosystem coordination that takes place when building the required data infrastructure by *Coordinating across multi-stakeholder data ecosystems for technology developments*. In line with this, as expressed by senior consultant from Lambda on how solutions are developed with the maritime industry:

"we are doing the data warehousing, smaller party is doing the data collection on the ship and some other company has doing the reports out to official companies. […] then you have the Shipping companies as in like kind of man in the middle […] So then you are always talking via another person."

While the development of any solution also requires *Conducting multi-stakeholder requirement gathering*, reflecting the embedded nature of most operations.

The partnership extend depends highly on the nature of the process under analysis but external coordination seems to be mostly required. To quote some examples: *Identifying shipyards as an important partner in driving for digitizing operations, Leveraging OEM partnerships for digital capabilities* or *Identifying port authorities as a major influence for industry standardization*. The later mention of port authorities reflects the recurrent statement made about port authorities as a major stakeholder in standardization and cross-organization coordination efforts, given their particular role in the ecosystem (Appendix D). An example is the statement made by the technology head of Alpha:

"if the ports will start to align their definitions, for example, how they communicate with vessels, carbon regulations about emissions and reporting, […] much more strictly (would influence) to have better data and information."

Aligning supply chain partners with sustainability goals, which summarizes the judgement of Omega from the end side of the supply chain as a customer when involved in AI-driven and sustainable efforts further confirm that partnerships must enable integrated value creation across multiple organizational objectives. While *Building financial stability through long-term* *customer partnerships* from the side of shipping operators emphasizes that partnerships should support sustainable business continuity rather than purely technological and capabilities access.

This last theme within value co-creation serves as the overarching feature in the aggregate dimension, as it emphasizes the multi-stakeholder coordination across all the previously discussed topics for sustainable AI adoption. Value co-creation ensures that AI-capabilities are developed through ecosystem collaboration while maintaining competitive advantages and operational autonomy. Lastly, partnerships established create a continuous improvement cycle where insights from pilot projects and ongoing developments inform future technology and capabilities selection criteria.

4.3 Value Co-delivery: AI-enhanced services

This dimension covers the themes of operational enhancement and service delivery evolution that enable organizations to improve core value propositions through strategic AI integration as derived from the conversations with various decision-makers. It was also emphasized that existing service capabilities should be improved, while novel AI-enabled offerings are in development, thus increasing competitive features without disrupting proven operational models.

The following themes summarize the acknowledgement that successful service evolution in the maritime context requires careful enhancement of existing capabilities, strategic customer experience improvements, collaborative ecosystem integrations, and optimization of operational intelligence. Actors involved highlighted than rather than seeking implementing of new technologies or developing new competences they would prioritize the augmentation of incumbent service delivery methods supported by AI, with the goal of increasing customer satisfaction and operational performance, which are critical factors in an industry relying on strong relationships and service reliability that directly relate to long-term commercial viability.

4.3.1 Current Value Delivery Assessment and Enhancement

As part of the service transformation process, it was highlighted during conversations that maritime operators must begin by conducting a thorough assessment of current service delivery mechanisms to identify improvement opportunities within the existing operational framework. This starts by *Identifying core service-based revenue streams*, to protect existing value delivery propositions that directly impact the sustained operation of the organizations, thus companies need to understand their value delivery baseline before taking on transformation initiatives.

Delivering core value independent of AI visibility, better summarizes the sentiment of interviewees who also recognized that value propositions that directly impact customer satisfaction should remain consistent and reliable while internal operational improvements target to advance efficiency and service quality. As emphasized by the commercial head of Beta:

"we're a service provider. […] If we look at our line of business, the, we ship cargo from A to B, Nobody is nobody is actually requesting AI yet. As long as you deliver the cargo in a safe and sound condition to the port […] So I don't think our clients are, when it comes to the service we provide, AI minded. Of course they have their own AI challenges or development or whatever, but that is not yet touching ours. Nor the business we do for them."

Understanding these core value delivery mechanisms enables companies to systematically identify opportunities for reducing manual workflows and potential errors introduced. For instance, *Reducing manual work through automation* and *Digitalizing operational workflows to boost efficiency* exemplify how maritime companies can improve internal efficiency while maintaining customer service consistency. Furthermore, *Enhancing data processing with AI for accuracy and efficiency* illustrate the opportunity to reduce operational costs and improve service quality by *Automating repetitive and monitoring tasks* of critical back-office operations.

Building on top of these efforts, organizations can focus on *Pursuing incremental performance improvements* and partial automation of processes, creating higher value while building organization confidence in AI competencies. This incremental approach prevents over-engineering solutions without proper understanding the core value propositions, ensures validation of investment decisions and guides future developments. As expressed by the key services manager of one shipping company, *Targeting partial automation of complex standard processes* can produce impactful outcomes with measurable improvements.

The adoption of these incremental improvements supports overall customer service improvement through enhanced responsiveness, accuracy and reliability without requiring customers to adapt to new systems or processes. Tangible outcomes of these developments would end up *Reducing error rates and improving service quality, Aiming for improved response times for customer service,* and in clear customers' demands such as *Enhancing supply chain transparency through cargo tracking*. Increased visibility summarizes one of the main goals in this regard, as expressed by the data & tech lead of Epsilon:

"our big goal is to answer them within xx hours which is quite a stretch from what we do now. And we want them to always have insight into the status of their project or the service that we are doing."

Incremental service improvements, as discussed by the interviewees, are concrete examples that customers and service providers alike can benefit from. These serve as the basis of sustainable transformations pathways that can bring forward enhanced efficiency, accuracy, customer satisfaction and support collaborative service integration. Thus, this theme is positioned under the value co-delivery dimension.

4.3.2 Digital Customer Experience Integration

As previously stated, customer satisfaction was a consistently discussed theme during the interviews. Some of the most prominent topics are expectations of operational transparency, proactive communication and service responsiveness. In this regard, many organizations have already been working on building closer customers relationships through digital touchpoints and improved services accessibility. *Enhancing customer proximity through data-enabled services*, refers to strategic technology implementations that allow clients to derive greater insights from the operations of service they hire by providing improved visibility.

Organizations also reported working on better customer experience by improving efficiency across all customer interactions. For example, *Integrating AI into customer support for efficiency gains* through implementation of chatbots that handle basic queries before escalating to more complex human interactions. More significantly, shipping companies recognize higher value in *Automating routine customer communication* and *Automating customer updates through integrated AI systems* which can significantly improve response times and communication consistency, freeing up time of customer relationship employees to focus on more impactful tasks as indicated by the services manager of Beta:

"I think especially the operators […] they're taking quite a bit of time to inform all the customers of the whereabouts of the ships. If we can find a way how to process this data by AI for instance, […] that would enable them to focus more on the work where that makes a difference."

Building on efficiency improvements, ecosystem companies are also focusing on *Implementing on-boarding to improve technology adoption* across stakeholders. In this way, driving digitalization and integration further across the ecosystem. While other organizations such as Sigma also saw potential in *Delivering AI-enhanced customer service* by providing AI-supported tooling for customer service representatives. This also underscore the need for sustainable customer experience transformation by keeping human in the loop.

The benefits of this integrated approach extend beyond operations efficiency to meaningful business value delivery. As summarized from what the tech lead of Epsilon expressed about the motivations to invest in AI-technologies, *Capturing value through customer loyalty enhancement* represents the ultimate objective of value co-delivery innovation. Strengthening commercial relationships through superior service delivery creates sustained competitive advantages in a market where long-term partnerships and trust directly impact commercial success. The collaborative nature of these improvements generates compound benefits across customer relationships. The overall perspective is that by refining communication consistency, faster response times, better information access and superior employment of human expertise, stakeholders become more engaged partners in operations optimization and service delivery initiatives.

4.3.3 Collaborative Service Integration

Another theme extensively discussed during the interviews what the requirement for cross-organization coordination for collaborative service delivery. As previously stated, carrying out activities in the industry unavoidably imply the involvement of multiple actors, therefore any effort for improvement in service delivery necessarily includes those involved in the operational process, plus those supporting its development. This theme addresses the collaborative nature of AI adoption for service delivery and its dependence on coordinated operations across ports, terminals, shipping lines, regulatory authorities and technology partners through systematic integration of data, standardization of communication protocols across multiple platforms.

To begin with, effective service integration start by *Enabling cross-actor collaboration through data sharing*, as expressed by an innovation manager from Theta, comprehensive data integration is becoming more relevant:

"we also see is that data sharing becomes more and more important so. To optimize your logistics chain or to optimize processes in the port area you need to work together with different parties. Actually you need to exchange data"

Which is also of interest for regulatory agencies who also carry out efforts for *Establishing cross-stakeholder data sharing* for increased auditing capabilities, which is supported by an adequate data infrastructure development.

Furthermore, effective communication requires standardization of communication protocols that enables unobstructed information exchange and uninterrupted operations across diverse technological platforms. Here Alpha reflected on the challenge of operating across multiple regions with different standards, thus *Prescribing cross-industry standardization of communication protocols for automation*, especially when it comes down to coordination with terminals and port authorities.

On the other hand, shipping companies looking into digitizing their operations also deal with multiple service providers pushing for increased assets connectivity. However, it seems rather complex having to deal with multiple platforms for monitoring assets they already own; thus, *Creating integrated customer digital experience platforms* was proposed as a more feasible solution.

A particular observation that emerged in multiple occasions was that ports and terminals emerge as critical coordination hubs that enable service delivery synchronization. A critical moment of the shipping operation occurs when arriving or leaving the area of the terminal and ports, so many efforts are currently focused on *Digitizing port workflows for customs and cargo handling as a business model innovation*. This not only increases visibility but also supports efficiency in the supply chain, as the financial head of Alpha stated:

"And then it's yeah, the customer is one side, but the receiving end of the cargo is the other side. So that's usually as a terminal way you have to bring the goods to, and that brings it to how can you efficiently get there? So there you have maybe port authorities or terminal authorities as an important partner and you can of course expand this."

Additionally, *Synchronizing with port operations to minimize waste and emissions*, refers to the perception that improved coordination can save fuel consumption and improve arrival planning as voyages can be optimized with better information exchange and updates. Therefore, higher integration can also reduce the environmental impact and avoid waste of resources.

These collaborative efforts create reinforcing dynamics that strengthen ecosystem partnerships and drive continuous improvement in service delivery. As organizations experience the benefits of improved coordination and operational visibility through costs reductions, higher compliance and improved customer satisfaction, they can deepen industrial relationships and expand the integrations. This theme falls under value co-delivery innovation because it focuses on optimizing existing service delivery networks through coordination and the support of advanced technologies.

4.3.4 Operational Intelligence Optimization and Reevaluation

One of the most technical sophisticated topics discussed was the usage of AI-driven solutions for decision support and operational optimization that enable superior performance. Optimizing performance of vessel operations using AI and machine learning is, in this regard, just an example of how ecosystem players are employing these technologies to improve operational efficiency. However, it was also highlighted that preserving human expertise ensures safe and effective operations, about this, the co-founder and financial manager of Zeta indicated:

"So it's basically a very big puzzle with small pieces in there. […] and so for us it's more and more on sort of seeing how can we use data, how can we use AI to provide the operator with

actual feedback that they can sail more safely, more sustainably, without having directly get rid of the human there."

Operational excellence, as discussed, depends on operational intelligence to ensure optimal resource utilization, risk mitigation and increased performance. For instance, by *Enabling decision-making through real-time dashboards* and *Employing AI in time-constrained decision making* can derive data-driven insights to make effective decisions under dynamic and complex conditions.

Moreover, the evolution from reactive to predictive maintenance is on a high degree supported by better data infrastructure and *Transitioning to predictive maintenance models* enables proactive optimization strategies that ensure service reliability, reduce costs and even reduce emissions. This is particularly essential given the high cost of assets downtime and the safety-critical nature of maritime operations.

Highlighting the potential of AI to improve expert's decision capabilities, another decision-maker pointed out during interview 18 that the application of these technologies could be used specifically for *Enhancing weather routing optimization*. This again makes explicit reference to the need of keeping people in control of the process for making critical decisions.

What is more, this operational intelligence evolution extends beyond individual decision improvement but also supports systematic performance optimization that benefits customers. By *Enabling proactive decision-making services*, customers can also move towards anticipatory service management strategies that can reduce complications in their end of the supply chain and preserve customer satisfaction, which also falls under the umbrella of value delivery.

This theme reflects on the analytical foundation and decision support capabilities necessary for collaborative optimization of service delivery. Moreover, operational intelligence drives continuous improvement across the entire value delivery chain and creates the tangible evidence necessary for further refinement of strategies adoption and development efforts.

4.4 Value Co-capture: AI-Enabled Revenue Models

This dimension summarizes the topics discussed around the critical process of capturing value that enables shipping companies to justify AI investments through measurable financial returns and tangible benefits. It emerges from the recognition that technology adopters in the maritime industry are fundamentally ROI-driven and require clear profit mechanisms to support continued technological advancements. On the other hand, the integration of AI-driven competencies supports the transition of regulatory compliance from cost and administrative burden to a competitive advantage that companies can potentially monetize.

On the other hand, although data monetization strategies are in place, these are still under development and are seen more as an add-on to existing capabilities rather than a completely new market. Nevertheless, collaborative value-sharing mechanisms allow for the distribution of costs as well as benefits across ecosystem participants and strengthen partnerships.

This dimension acknowledges that successful AI adoption drives not only operational improvements but also clear financial benefits, necessary to justify investment risks. Which also applies for undertakings targeting social and environmental improvements. Companies pursue environmental initiatives as long as they align with profit optimization, regulatory compliance requirements, or competitive differentiation opportunities. Therefore, emphasizing that successful business model innovation must demonstrate clear financial benefits while achieving social and environmental responsible outcomes.

4.4.1 Efficiency-Based Profit Optimization

Most relevant value capture mechanisms discussed focused on immediate cost reduction through operation efficiency. Supporting that this remains the principal driver for AI investment decisions. As highlighted by the first-order category *Seeking cost-saving technologies due to competition*, the fundamental challenge is to provide tangible returns on technology investments.

Some of the clearly identified avenues for this is *Capturing value through fuel-related cost reduction*, as clearly expressed by the following quote from a business optimisation lead of Alpha about the motivation of the organization for driving sustainability:

"I think that's a universal thing within shipping, like the margins are really low, there's always a high risk involved and the margins are quite low. So also investments into sustainability is second choice. Let's say the first part is writing black numbers. […] if you sail more efficient and therefore uses less fuel, which is more sustainable and directly impact your operational costs. So that is, in my opinion, the incentive to go green"

Which also makes emphasis on *Prioritizing profitability over sustainability in investments*. Demonstrating that companies approach AI implementation or any other technology implementation for that matter through a strict cost-benefit analysis, with fuel usage optimization representing the largest opportunity for immediate returns; thus, *Reducing operational costs through AI optimization.*

This is further emphasized by *Monetizing on fuel efficiency improvements as a driver for innovation* and *Achieving rapid ROI through fuel optimization.* Indicating that successful AI implementations must demonstrate impact on one of the largest operational cost elements.

Other ecosystem players such as ports also focus on *Creating efficiency-based pricing models*, by providing benefits to operators with demonstratable more efficient operations. This approach allows shipping companies to capture value on top of cost savings. In this regard, about how other organizations in the ecosystem support shipping companies, the tech lead of Gamma indicated:

"(Ports) are incentivizing them (vessels) to come with better utilization of the vessel. So it doesn't mean bringing more cargo each time, so it that this visit is more sustainable for from the perspective of the vessel. So instead of for example carrying 1000 TEUs and then crossing the ocean or crossing long distance with this amount of cargo (ports) are giving incentives for them to come with, let's say 2000 TEUs and this means that this trip had a better efficiency in terms of how much cargo it transported in terms of fuel consumption."

This topic theme belongs to value co-capture dimension, as it establishes the fundamental economic justification for AI investments. In a way, this represents the foundation for subsequent value capture mechanisms by providing confidence and evidence necessary to support more complex projects and sustained partnerships.

4.4.2 Performance and Compliance Value Integration

A rather interesting theme emerging from the interviews was the discussion of regulatory compliance as an administrative and monetary pressure, but also as a potential competitive advantage and revenue opportunity. This theme focuses on the usage of AI technologies to improve value propositions that address compliance topics.

As it's the case with other themes, data availability is of the upmost importance. In these scenarios, shipping companies often resource to expert assistance that focus on *Supporting clients with centralizing sustainability data for regulatory reporting*. While other organization, such as Kappa, go a step further Using *AI to enhance ESG compliance*, for shipping companies and many more. Here an account executive expressed how external support help in developing solutions with this specific requirement at hand:

"we help them with ESG management. So environmental, social and governance. So, for sustainability data and the data collection, but also using AI features on top of that for missing data or to do predictions."

Other interviewees discussed the value of compliance as a competitive advantage. For instance, one shipping company representative mentioned *Using sustainability initiatives as competitive differentiators* when competing for a contract, as this could incline the balance in their favour. While another company's representative also stated the benefit of *Using safety compliance recognition as a competitive advantage*, as safety is a very relevant topic in this industry. More specifically, as an example, the business optimisation lead of Alpha indicated:

"and then you get a statement of compliance. And it's also I think a trade enabler that if you can prove with statistics and with those certifications that […] safety is good […] on the vessels, then it will give you an advantage."

These first-order categories reveal how superior compliance capabilities provide market differentiation and negotiation opportunities.

On the other hand, operational improvements in compliance procedures are also regarded as beneficial by implementing solutions that support *Monitoring emissions for regulatory compliance*. And by *Freeing resources by automating sustainability data workflows*, employees can focus their attention in reducing environmental impact rather than working on administrative tasks.

Nonetheless, ecosystem actors also reported intrinsic interest for higher accountability and compliance by *Responding to sustainability expectations with emission tracking*. As indicated by the commercial head of Beta:

"make sure that we remain profitable. That is like an important part. […] but also […] we need to do something on being sustainable, right? We cannot do what we used to do like 15 years ago. […] people want to know how much CO2 or we're emitting."

While *Addressing the influence of the government in regulatory sustainability compliance* by defining appropriate reporting procedures and clearer paths for accomplishing decarbonization goals.

The transition of mandatory compliance into a competitive advantage and revenue opportunities is enabled through a network of relationships between authorities, operators, service providers and end customers. By leveraging AI to streamline and exceed regulatory requirements, companies create market differentiations while improving performance. Thus, this theme is placed under the value co-capture dimension.

4.4.3 Data Monetization Strategies

Emerging opportunities for new revenue streams were identified by some interviewees, specifically from operational and compliance data generated through AI implementations. Although the organizations in the ecosystem don't consider those data products and services as potentially replacing current core operations, they anticipate the emergence of new enhanced and more integrated services and improved negotiation competences.

Improved operational visibility value is emphasized by *Offering service-based pricing through subscription models*. This refers to the possibility of establishing new contractual agreements for maintenance services based on the opportunities provided by predictive maintenance capabilities. Showing how companies are transitioning from transaction-based pricing models to recurring long-term agreements enabled by continuous data generation and analysis.

Similarly, the evolution of service models, as exemplified by *Creating data-driven business extensions for providing visibility of the operating activities*, reflects on how more mature players are capitalizing on their established data infrastructure by creating new data products that hold potential value for other ecosystem players. Moreover, this growing abundance of information creates opportunities for the emergence of new actors focused on the aggregation and transformation of this information into more sophisticated services. For instance, an innovation lead of Theta indicated:

"at least the bigger companies are actually adding business models to their usual business by creating platforms with their data, which is very useful for other parties and arrival times estimations and stuff like that, […] They noticed that you could extend your business using data you actually already have, but then creates a paid platform out of it. And I think other and new companies arise that they don't do anything operational themselves, but they just combine data from different parts in the logistics chain and create an advantage if you become part of their platform."

Additionally, Beta's representative reflected on how transparency can also influence pricing and customer choices by *Considering CO2 transparency to influence commercial decisions*. Since various customers already demand greater access to data on voyage emissions from different service providers, this could be used in the future during business negotiations and contract discussions, similar to the dynamics already observed in voyage fuel selection.

Lastly, the potential development of a platform or a marketplace was also discussed. During conversations around the topics of Port Community Systems, one of Gamma's interviewees mentioned noticing features *Developing data marketplace capabilities*, as the inclusion of non-essential data could also be monetized. While other shipping company representative reported *Anticipating platformization of maritime freight booking*, since the aggregation of currently dispersed services had already been observed in other industries.

By monetizing the insights and opportunities generated through AI systems, companies create new business models that could support continued technology investment and improve competitive advantages in emerging digital markets. This theme belongs in the value co-capture dimension because it encompasses the evolution from cost-saving and efficiency focused AI implementations to revenue-generating novel data products and services.

4.4.4 Collaborative Value Refinement

As emphasized by different roles interviewed, sustainable value capture in the maritime industry requires collaborative approaches that align incentives across ecosystem partners. This theme focuses on the development and optimization of value distribution mechanisms that enable multiple parties to benefit from AI-enabled implementations while maintaining competitive standing.

To begin with, as exemplified by a description of challenges in coordination on arrival times in which some actors would prefer to speed its own arrival due to individual preferences despite the higher costs and emission generated. In response, a reflection on a prerequisite was made on *Incentivizing joint optimization requires sharing and bringing visibility of logistics benefits*. As expressed by the CFO of Alpha:

"But then for the customer, it also has an incentive to help us together to do together a more optimized service by simply coming in time. So we reduce the fuel emission, the fuel consumption and the emission and the customer has a better service by not having to pay the demurrage and the trick is, of course, how are we going to redistribute the benefits that are related to a more just in time service?"

The influence of the market was also recognized through *Emphasizing the need of demand and support from clients in driving sustainability*, indicating that successful value capture requires active client engagement and shared value aspirations in sustainability initiatives.

On the side of service providers, for those involved in technology implementation, there is a clear value in *Transitioning to recurring revenue models for IT services*. Showing how technology providers are willing to develop sustainable commercial bonds that align their success with clients' operations improvements.

A very tangible example of effective mechanisms mentioned was the practice of *Sharing implementation costs with partners* when increasing assets connectivity for data generation for monitoring and predictive maintenance models. This shows how shared investments can support adoption of technologies and pave the path for future collaboration.

However, in an industry with these many layers of communication for carrying out operations, as stated by Gamma, *Aiming for ecosystem-wide problem identification* emerges as an appropriate strategy for identifying appropriate value distribution mechanisms. As illustrated by the example of *Redesigning incentive structures for efficiency and sustainability* in terminal arrivals. Demonstrating how successful companies can create instruments that align different parties' interests.

The analysis reveals that significant challenges exist in developing value capture mechanisms due to potentially conflicting commercial interests. Therefore, creating shared value capture models that address multiple participants needs can support the creation of sustainable competitive advantage. Multi-stakeholder cooperation proves necessary not only for continuous innovation and technology implementation, but also for the acceptance and adoption of sustainability and efficiency objectives.

4.5 Sustainability Benefits Realization

The fifth dimension discusses the outcome of sustainable business model innovation as a combination of measurable economic, social and environmental benefits. Operational adopters in the maritime industry recognize that concrete evidence is necessary to justify AI investments. In this regard, "sustainability" is understood as ensuring continuous operations and long-term resilience of the organization and the ecosystem.

The "benefits realization" part recognizes that successful sustainability must demonstrate clear return on investment while addressing workforce concerns and environmental improvements. Additionally, aside from compliance fulfilment, actors are also concerned with commuting their sustainability objectives with enhanced competitive advantage and operation excellence, which are critical factors in an industry with intense market competition and increasing regulatory pressure.

4.5.1 Economic Sustainability Integration

The insights derived from the interviewees established clear economic value as the foundations for justifying AI investments through measurable financial returns. Likewise, this theme focuses on the revenue opportunities and competitive edge derived from sustainability initiatives. The conversations revealed that shipping companies and those providing supporting services to core business activities such as maintenance require solid business cases that demonstrate immediate operations benefits alongside long-term sustainability goals.

To begin, *Requiring solid business cases for sustainability investment* emphasizes the financial viability required by the pressure-driven nature of operational adopters who cannot invest in sustainability initiatives that compromise profit. This constraint is a reflection of the price-competitive maritime market, as indicated by the financial head of one of the shipping operators interviewed, Alpha:

"Yeah, I think it's a lot about finding the immediate business case. [...] we have to write black numbers as well. So you cannot invest yourself to bankruptcy that that doesn't make any sense. So we need to keep finding the business cases and that can sometimes be financial and sometimes be more on the environmental part or the social part."

This approach is demonstrated in the discussion of the operational optimization focus, such as *Reducing fuel consumption through smarter control*. Where stress is made on how saving on one of the largest cost components can also drive environmental objectives. This dual benefit approach was highlighted in multiple occasions as noted by the CFO of Zeta about how their solutions support maritime operations:

"by saving fuel, let's say for some vessels, we save about 10 to 15% of fuel. So we save the actual fuel being bought by the operators or by the vessel owner. But it also saves a lot for the environment"

The efficiency focus is further emphasized through *Improving logistics through digital process optimization can lead to sustainability as a by-product*, suggesting that AI for operational performance can produce outcomes such as *Avoiding ballast trips to cut emissions and costs*, reducing expenses and environmental impact simultaneously.

However, the economic justification extends beyond cost reduction to other revenue opportunities. By *Earning sustainability incentives through operation improvements* shipping companies can access financial benefits provided by other ecosystems actors such as ports and financial institutions who value improvements in environmental performance. For instance, by obtaining a reduction in loan interest rates.

Moreover, *Considering premium pricing for sustainable services* indicates that these developments can impulse new pricing strategies supported by a differentiating factor. This transition from purely compliance obligation into revenue generating opportunities represents a critical change in sustainable value capture propositions.

This theme establishes the economic foundations that support social and environmental responsible initiatives. More than just an argument in favour, it provides financial stability required for continued innovation and expansion of those initiatives and the organizations involved.

4.5.2 Social Value Creation

The discussion on the social property of sustainability focused on the generation of workforce strength that improves operations reliability and continuity, as well as addressing ethical concerns about AI implementation. This theme recognizes that sustainable business model innovation must consider human impact and social responsibility alongside economic and environmental objectives. The conversations revealed significant attention to workforce concerns and the need for ethical and congruent AI deployment.

The workforce enhancement opportunity is illustrated by *Improving safety outcomes with AI-based risk detection*, which refers to how AI technologies can directly benefit crew management by reducing operational hazard and improving working conditions. This safety focus addresses fundamental safety compliance requirements, which are of major importance in the maritime industry, while demonstrating actionable business value.

The ethical implementation requirement is highlighted through *Addressing AI trustworthiness in critical applications*, which reflects on the need for reliable AI solutions that enhance rather than compromise human decision-making. This trustworthiness concern is particularly relevant in the application of these technologies on maritime operations in direct contact with regulatory agencies who favour *Integrating a long-term view for sustainability*, and where failures and lack of diagnosis capabilities can have serious safety, environmental and reputational consequences. In this regard, the Iota models specialist expressed:

"I feel like the paradox of AI, […] you want to use it for off-design conditions. But then also you want to know, is it really trustworthy in these off-design conditions? Is it correct what it predicts or calculates or is there some sort of reproducibility, a predictability to what the result is?"

Additionally, by *Addressing ethical AI supply chain concerns* during interview 20 it was highlighted the lack of visibility into the operation that supports the deployment of AI models, particularly in the case of generative AI.

On the other hand, social value creation extends beyond workforce protection to broader stakeholder engagement. The first-order category *Responding to client social sustainability demands*, also reveals the interest of customers for increased reliance and visibility in socially responsible operations, as this becomes part of their supply chain, as expressed by the business optimisation coordinator of Alpha:

"There's also clients that actually now are performing due diligence on us on human rights, for example, they really ask us, OK, how are human rights within your organization's, how are they settled and also at our suppliers and they actually want proof on it."

As described, social value creation reinforces economic sustainability through improved workforce support and customer loyalty and well as public accountability. And financial support can drive increased efforts in social responsibility. Thus, this theme is contained in the sustainability benefits realization dimension.

4.5.3 Environmental Impact Optimization

The environmental impact theme is the third element in the scope of sustainability benefits realization, where AI driven operation improvements deliver measurable environmental outcomes that strengthen economic performance and social value. Interviewees further stressed that achieving environmental improvements aside from satisfying regulatory requirements can also demonstrate competitive benefits through improved operational performance. These conversations also revealed the critical importance of developing data infrastructure and monitoring mechanisms to validate environmental benefits.

On one side, as part of the compliance element, stress is made on *Balancing environmental and social goals in sustainability strategy* under the umbrella of the CSRD responsibility, which refers to establish feasible commitments and measurable goals across time. Additionally, in order to commit to long-term initiatives, it is important for operators to see higher potential in compliance activities by *Emphasising sustainability initiatives as compliance requirement and as business case*. Which refers to the double value conceptualization of sustainability from burden to strategic advantage.

The dual benefit nature and collaborative aspect of these AI-driven initiatives are exemplified by *Reducing idle emissions with AI-enhanced port scheduling*. Which shows how AI-enabled collaboration with ecosystem partners can achieve environmental benefits. Further emphasising the value of collaboration in maritime operations, especially in sustainability initiatives. Similarly, by *Leveraging technology for emissions tracking*, shipping companies can support both compliance reporting and operational improvements. These efforts require multi-stakeholder collaboration for data accessibility and strengthen cross-organization communication. As indicated by the data & tech lead of Gamma:

"we try to create or to use technology to, first of all, monitor what's going on, because this is not something that is as easy as it seems. [...] But we also coordinate with the customers and the players around and also getting data sources when needed to have an understanding of how much emissions they have"

However, many interviewees also reported *Struggling to measure the impact of technology-based sustainable solutions due to poor data availability*. This reveals a critical constraint in environmental benefits realization and investment justification, where companies cannot verify their environmental claims due to inadequate infrastructure. This measurement gap undermines the credibility of these initiatives and limits access to further incentives. Here, the CFO of Alpha reflected on previous technology implementation experiences with sustainability in mind:

"The other challenge was that it's actually […] quite difficult to really measure the impact […] quite well. You need a lot of data points to be able to eliminate any impact from wind and swell and any other external factors to really find out what's the benefits […] was and something we have heard also from other companies. You don't typically read that in the headlines of the newspapers, but I believe it's still very difficult to measure the impact."

On the contrary, a rather complex issue emerged during most conversations about *Managing AI sustainability trade-offs*. This acknowledges that due to the still developing nature of AI technologies, their implementation creates environmental impact through energy consumption that must be balanced against operational efficiency gains and claims of improved environmental performance with potential reputational risks. The discussion of this topic in particular demonstrates an evolving awareness about the usage of AI in the industry that considers a broader ecosystem perspective.

The last theme on sustainability benefits realization validates the collaborative nature of the elements of business model innovation and the interconnected nature with economic and social benefits, where feasible and measurable capabilities are indispensable. The realization of these benefits creates a self-reinforcing cycle where operational improvements drive economic, social and environmental value, thereby justifying continued investment in AI-driven sustainability initiatives.

4.6 Maritime AI Ecosystem: Stakeholder Roles and Influence on AI Adoption

The maritime AI ecosystem comprises different stakeholder categories, out of which 9 have been identified through this study. Each plays an important role in enabling, implementing and ensuring benefits from AI applications in maritime operations. Understanding these interconnected relationships is essential for successful AI adoption strategies. These roles emerged through the data analysis of the conversations with the organizations interviewed, a description of these is provided in the in table 4.2.

Maritime Services Operators: this group includes those organizations in charge of transporting goods across the water bodies and whose primarily objective is to bring the materials to the point of delivery. In this analysis, this group is the main operational adopter, meaning that this group serves as the primary transformation target of the study in charge of applying AI for shipping core operation activities. Common use case scenarios identified are: route optimization, cargo tracking, fuel efficiency, emissions monitoring, fleet management, remote monitoring, and environmental forecasting.

Port & Infrastructure Managers: this group manages the infrastructure necessary for carrying out shipping operations including ports, inland waterways, and intermodal facilities. Also, they regulate the arrival and departure processes to ensure safety and interrupted cargo flow in its surrounding. During the analysis, it was described as a key stakeholder in driving standardization of communication protocols, policy enforcement and coordination activities critical to improve ecosystem-wide operational efficiency. Use case scenarios of AI include: traffic control, port logistics, dredging planning, policy implementation, predictive maintenance, CO_2 monitoring.

Technology Developers: specialize in creating AI-powered solutions specifically designed for maritime applications. These organizations combine deep domain expertise with advanced AI capabilities to address unique operational requirements, safety standards and regulatory constraints through data integration and automation. This group drives the adoption of maritime AI applications by translating complex AI capabilities into accessible and proven solutions that reduce implementations risks and developments costs.

Table 4.2. Ecosystem roles description and companies mapped

Ecosystem Role	Companies	Role description in relation to AI adoption
Maritime Services Operators	Alpha, Beta, Omicron	Use AI for route optimization, cargo tracking, fuel efficiency, emissions monitoring, fleet management, remote monitoring, and environmental forecasting.
Port & Infrastructure Managers	Gamma, Iota	Implement AI for traffic control, port logistics, dredging planning, policy implementation, predictive maintenance, CO_2 reduction.
Technology Developers	Zeta	Develop technologies that integrate AI capabilities for automation, data integration, and predictive analytics.
Digital Transformation Partners	Lambda	Supports companies on the adoption of IT and AI capabilities, supports with strategy definition, technology selection, and integration development
Knowledge & Innovation Partners	Theta	Drive research, pilot AI applications, and foster academia-industry collaboration.
Equipment & Maintenance Providers	Epsilon, Delta	Provide equipment procurement and maintenance services, enable AI through connected hardware, sensor integration, and condition-based maintenance data.
Sustainability & ESG Enablers	Kappa	Provide AI tools for ESG performance tracking, compliance automation, and sustainability reporting.
Shipping Services Customers	Omega	Contract out shipping services, demand service reliability that can be enhanced by AI technologies
Financial Institutions	Sigma	Finance AI-related maritime upgrades, sustainable infrastructure, and innovation initiatives.

Digital Transformation Partners: functions as dedicated consulting and implementations organizations that provide comprehensive support for maritime companies in their AI adoption journeys. These combine technical knowledge of advanced technologies with organizational change management practices and strategic planning to guide operators through the implementations process while minimizing the risk of operational disruption and maximizing value. Fundamentally, this group provides the ecosystem with the specialized knowledge that most operators lack internally, thus reducing implementation complexity. Regardless of the applications selected, they should be able to support with strategy definition, technology selection, and integration development.

Knowledge & Innovation Partners: encompasses research applied institutions, universities, innovation labs, and industry partnerships that drive fundamental innovation processes. These organizations focus on conducting applied research and facilitate knowledge transfer between academia and commercial applications. Their research discoveries and talent development efforts create the foundation necessary to build initial applications that promise to become capabilities that will shape the future competitive landscape.

Equipment & Maintenance Providers: this group support continuous operations of the shipping industry by providing and maintaining essential maritime equipment including engines, propulsion systems, auxiliary machinery, and spare parts. Maintenance services are among their main sources of income, thus ensuring high quality in key to ensure long-term relationships with operators. They serve as a critical enabler for AI-adoption by integrating data capture and monitoring capabilities into essential equipment, making operational optimization and predictive maintenance accessible.

Sustainability & ESG Enablers: provide services and AI-enhanced solutions that help maritime organizations achieve environmental, social and governance objectives. They focus specifically on translating sustainability requirements into measurable outcomes. Among their main AI-applications are monitoring, report automation, and optimization systems for more efficient compliance processes. Similar to digital transformation partners, provide the required knowledge to navigate complex compliance processes that have emerged from the mounting pressure of regulatory frameworks. They serve an essential role to ecosystem players seeking to achieve sustainability goals in line with their operational needs.

Figure 4.2. AI Sustainability adoption influence mapping (Self - illustration)

Shipping services Customers: the end users of the maritime transportation services, including retailers, manufacturer, commodity traders among other that contract maritime operators for cargo transportation. As highlighted in 5.2.2., customers increasingly demand transparency, visibility and service reliability influenced by digital servitization in other industries, as well as sustainability compliance due to regulation in their own sectors. Related AI applications include customer service and engagement services, improved communication processes, real-time visibility and tracking solutions, chain value integrations applications. They influence the adoption of AI technologies through their demand and service expectations, as well as the financial incentives they can afford for enhanced services. Furthermore, they act as the end of the value chain who can provide validation of the success of AI-applications.

Financial Institutions: these include banks and risk assessment services that enable AI maritime investments such as infrastructure updates, technology implementations and innovation initiatives. Additionally, they can also influence the adoption of more social and environmental responsible practices through financial incentives tied to results from these initiatives. Since the industry is capital intensive and price competitive, their willingness to finance AI projects directly impacts the operator’s ability to pursue costly initiatives.

The mapping and analysis conducted on each of the ecosystem players roles, illustrated in figure 4.2. exemplify the claim that effective adoption of AI technologies for Maritime Services Operators is highly influenced by the coordinated engagement with multiple ecosystem players. Moreover, to deliver significant sustainable outcomes while maintaining operations continuity and competitive advantage, support is necessary from those that aid in the transformation process as well from those capable of incentivizing it and not only enforce it.

5 The AI Sustainable Business Model Innovation Framework (AI-SBMI): Developing AI-Driven Transformation in Conservative Industries

The maritime shipping industry stands at a critical moment where technological advancements, regulatory pressure, and sustainability demands meet to push fundamental transformation in how companies operate and create value. Following the presentation of the findings, the resulting framework presents a systematic approach for AI-driven sustainable business model innovation specifically designed for operational adopters in the maritime industry, addressing the unique constraints and opportunities that characterize this globally impactful, yet traditional industry.

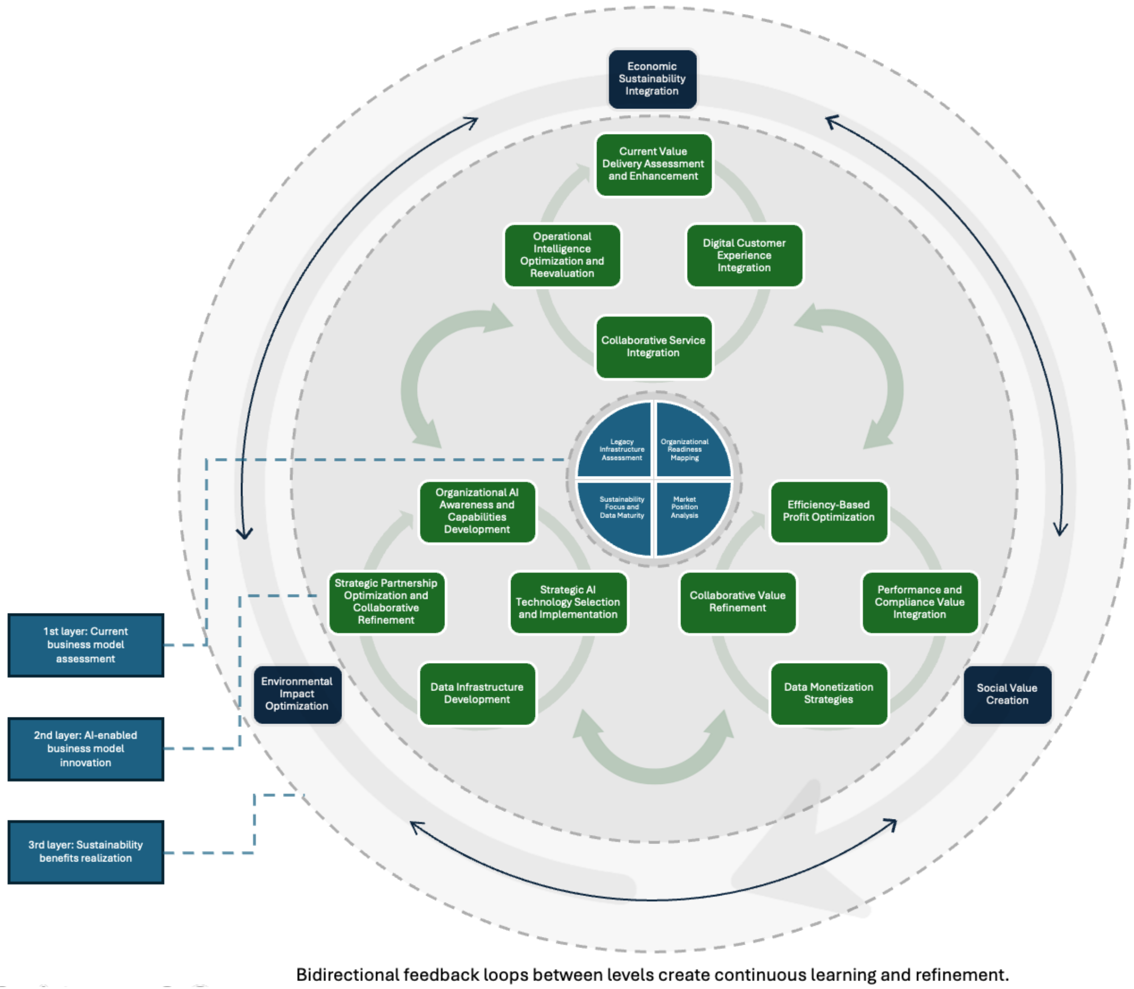

Figure 5.1. The AI Sustainable Business Model Innovation Framework (AI-SBMI) (Self - illustration)

As represented in figure 5.1., the multi-level architecture of the framework recognizes that sustainable AI implementation in maritime operations requires iterative, feedback-driven development across the five dimensions presented before. In contrast with technology-first approaches, this framework positions AI technologies as an enabler of sustainable value creation through business model innovation, rather than making it the end. The cyclical nature of its composition serves as an illustration that capability development and optimizations is a continuous process that evolves with market conditions and progression of technology maturity, bidirectional feedback mechanisms support continuous learning and refinement across levels, creating a dynamic learning system. Furthermore, the absence of an ‘end point’ mirrors the conceptualization that sustainable AI developments require ongoing iteration and refinement. Which is particularly relevant for operational adopters who must balance innovation with operational stability and financial performance.

5.1 Level 1: Current Business Model Assessment

This first level focuses on the comprehensive analysis of the organization readiness before taking on AI-driven initiatives. This level recognizes that maritime companies operate under characteristic constraints, including extended asset lifecycles, legacy infrastructure dependencies, cultural barriers, safety and service reliability prioritization.

This stage requires the participation of multiple ecosystem players with distinct responsibilities, starting with **maritime service operator** as the main subject of the assessment; **digital transformation partners** leading the diagnosis process and providing strategic guidance; **equipment & maintenance providers** contribute with technical assessment of existing equipment and associated data; **port and infrastructure managers** participate with ecosystem readiness evaluation and data sharing capabilities.

Figure 5.2. Framework - 1st level: Current business model assessment (Self - illustration)

As shown in figure 5.2., this evaluation encompasses four critical evaluation areas that determine the readiness for adoption and strategic direction. Legacy infrastructure assessment addresses the fundament technical constraints that characterize maritime operations, where vessels and related equipment often operate over 15 years (Appendix F) with infrequent modernizations opportunities due to high costs. This is consistent with Durlik et al. (2024) in which reliance on legacy systems which are incompatible with modern technologies is identified as a major barrier to AI adoption. **Maritime service operator** and **equipment & maintenance providers** can support here with evaluation of existing data capabilities of maritime engines, propulsion systems and auxiliary machinery. During this process, opportunities for sensor integrations, data collection and quality improvement should be identified.

Organizational capability mapping focuses on the human and organization culture factor that can determine AI adoption success. Since employees and management within established maritime companies can demonstrate cultural resistance to change due to uncertainty or even fear of job displacement (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). **Digital transformation partners** lead this evaluation, working closely with people from the **maritime service operator** to assess leadership readiness, workforce concerns and cultural barriers that must be addressed before the deployment of technical solutions. This is highlighted due to the strong evidence of cultural resistance to digital transformation in the industry; therefore, this will support a tailored development of change management strategies.

Market position analysis evaluates the competitive dynamics and strategic stance that influence AI investments priorities and implementation strategies. In fact, in mature industries such as maritime, intense market competition often drives actors to compete for value capture rather than value co-creation, limiting collaborative opportunities (Costabile, 2024). To navigate this landscape, **maritime service operators** should evaluate their current market standing as well as its strategic priorities for long-term growth. Furthermore, understanding market needs is also necessary because customers are increasingly demanding sophisticated digital services that impulse business model innovation (Kolagar, Parida, & Sjödin, 2022). **Port and infrastructure managers** contribute to this stage with their perspective and guidelines for sustained growth of the industry, and proactive engagement with regulatory entities is essential for the creation of adaptive policies (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

Sustainability focus and data maturity assessment establishes the foundation for environmental, social and governance capabilities that will support subsequent sustainability integrations efforts. By understanding sustainability objectives, organizations can define the AI solutions that best align with their goals and measurement capabilities (Sjödin, Parida, & Kohtamäki, 2023). **Port and infrastructure managers** provide the regulatory and policy frameworks that shape the focus and prioritization of activities. **Digital transformation partners** can assess the availability of information necessary to implement a solution that commutes the maritime operator's sustainability priorities with compliance requirements. This evaluation recognizes that sustainability performance is increasingly influenced by external factors such as regulations and market demands.

This initial evaluation ensures that future implementations efforts build upon realistic organizational and technical capabilities, as well as strategic focus and market demands. Drawing from the learnings of AI x sustainability conceptual framework, this analysis can support decision makers in assessing the AI initiatives against their corporate strategies and resources (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). This baseline feeds the following level of business model innovation with the required information to develop strategies that reduce the risk of failure due to limitations such as organizational absorptive capacity or operational requirements.

As an illustration, the case of the Maritime Service Operator Beta will be used. This company operates in Mediterranean trade lanes providing dry bulk shipping services. Starting with the infrastructure, they own an ageing fleet with a medium ship age of over 18 years, conduct manual fuel monitoring, possess limited connectivity at sea and use an industry specific ERP with no integration to other services. Thus, this infrastructure cannot support advanced AI application. As for the organizational readiness evaluation, they have no dedicated role for innovation or data-driven solutions development, the CEO and CTO are interested in exploring AI capabilities, operational personnel have limited experience with digital modernization projects and seem sceptical of new tools. Additionally, as for the market positioning assessment, direct competitors offer similar services, but Beta is considered very flexible in terms of planning and cargo capabilities by their customers, while conducting a service they emit reports periodically manually elaborated, don’t provide real-time tracking, operate under thin margins, and can’t access to bigger contracts due to this limitation. Finally, as for the sustainability focus evaluation, the organization can’t provide carbon tracking despite other competitors doing so, it arranges preventive maintenance with between 3 and 4 months of delay, they will be subject to CSRD reporting from 2026, and they hire a third-party company to assist in the elaboration the reports for EU-ETS.

This assessment provides critical insights for subsequent innovation efforts and to prevent costly failed AI implementations. Additionally, since the company doesn’t have a dedicated role, it contracts services from the digital transformation partner to assist in this stage. This also ensures that level 2 cycles are grounded in actual organizational capabilities rather than only technology aspirations.

5.2 Level 2: AI-enabled Business Model Innovation

This level encompasses the three interconnected dimensions of business model innovation enabled by the adoption of AI-technologies. This level represents the core transformation process of maritime operations, evolving into technology-enhanced and data-driven processes.

The iterative nature of these dimensions represents the continuous refinement processes of business model innovation informed by operational learnings, market feedback and evolving regulation. Each dimension illustrated in figure 5.3. operates as an iterative improvement cycle where initial implementations generate insights that inform following developments.

5.2.1 Value Co-Creation Through AI and Collaboration

The co-creation approach recognizes that successful AI implementation requires integrations of diverse perspectives and priorities across the maritime value chain. As Kolagar (2024) highlights, the process of digital servitization and its role in achieving sustainable benefits requires the coordinated efforts of multiple actors within the ecosystem to co-create value propositions. Building on the insights derived from the previous level of assessment, organizations can make informed decisions with respect to the areas to prioritize at this stage, ensuring that technological development is aligned with shared goals and ecosystem wide impact.

The first step is to develop organizational AI awareness to build internal understanding of technology capabilities and limitations before significant investments. This is in line with the suggestion that organizations benefit from clear understanding of digital servitization before implementations and improve the possibilities of making digital-service-oriented decisions (Kolagar, 2024). Here, **digital transformation partners** guide **maritime service operators** in their journey of value discovery and creation, ensuring it aligns with operational requirements and strategic objectives. More importantly, as discussed in the analysis, it’s important that personnel at different levels of the organizational structure develop this understanding to be able to spot key opportunities for technology selection and provide the support needed during the uncertain implementation process under realistic expectations. Thus, this applies to both top managers and employees, responsible for the organization's digital future (Kolagar, 2024).

Once this is established, the organization can progress towards strategic AI technology selection. Aligning AI initiatives with corporate business strategy is crucial to generate long-term value, operational improvements and supports the development of more advanced competencies over time (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024). **Knowledge & innovation partners** play a crucial role by providing insights into on-going research, technology progression and proven applications that support informed decision-making. Usually, these partnerships are conformed by networks that include different **technology developers** that can demonstrate practical applications through pilot projects and proof-of concepts. Ultimately, the operator aided by the **digital transformation partners** will define the capability most adequate to build, keeping in mind the business cases that it desires to focus on.

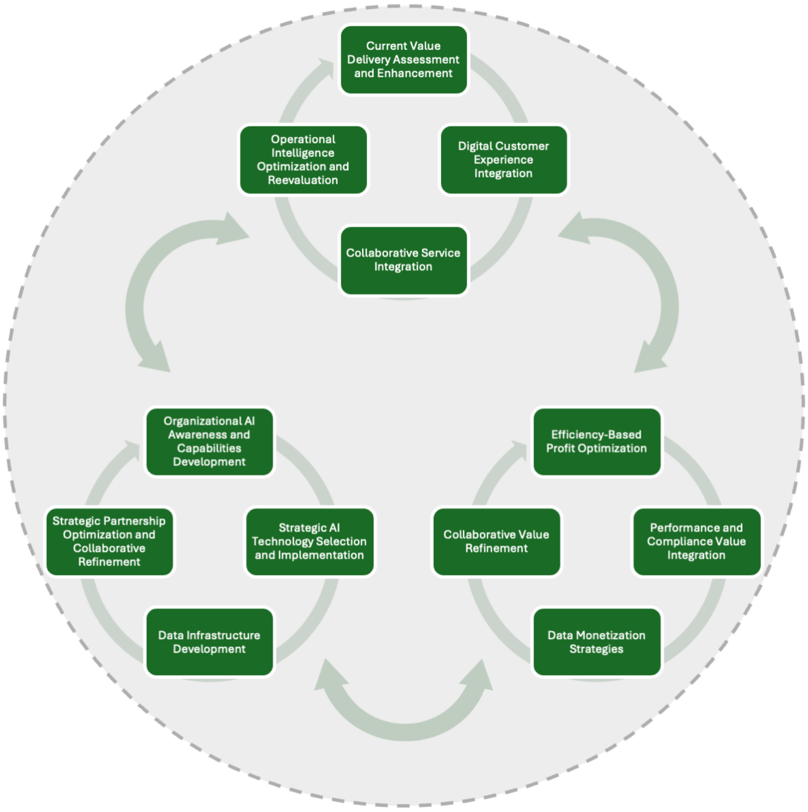

Figure 5.3. Framework - 2nd level: AI-enabled business model innovation (Self - illustration)

Subsequently, the required data infrastructure must be developed based on the foundational assessment of the first level. This encompasses the systematic and targeted improvement of data collection, storage and processing solutions ensuring quality and availability of information, which AI systems rely heavily on for training and operation (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). **Equipment & maintenance providers** can support this process with the integration of solutions compatible with existing equipment, as well as sharing knowledge on related experiences with their network of clients. Additionally, **port & infrastructure managers** participate by developing and informing the ecosystem on data sharing protocols and requirements that enable coordinated implementations across the maritime landscape.

Therefore, strategic partnership optimization and collaborative refinement is required to establish the network that will provide the support necessary for the proper development of AI-capabilities and fine-tuning for the specific adopter. The main reason for this is that developing AI solutions often requires specific competencies scarce in most organizations; therefore, partnerships with specialized knowledge providers are necessary for continuous value discovery (Sjödin, Parida, & Kohtamäki, 2023).

Initial AI implementations often begin at a small-scale and provide feedback and information to be used in next iterations. These initial learnings and new opportunities for improvements and expansion, requiring collaborations with the partners selected to adapt solutions to evolving market and organizational needs. The need for ongoing capability refinement based on these experiences will drive further developments.

For the practical case of maritime service operator Beta, the value co-creation journey begins by leveraging their core strength, operational flexibility, while addressing infrastructure limitations through strategic partnerships. Recognizing that their ageing fleet and ERP software cannot immediately support advanced AI applications, Beta, guided by the digital transformation partner, collaborates with a technology developer to implement a phased connectivity solution, starting with basic IoT sensors for fuel monitoring, and low-orbit internet access. Then, the digital transformation partner defines a data storage and processing solution compatible with Beta's current productivity software to consolidate new and future data. The company also appoints their most tech-savvy operational manager as 'Digital Operations Coordinator' to work closely with the digital transformation partner as a functional lead while providing AI literacy training to crew members. Through collaboration with port infrastructure managers, Beta gains access to standardized data exchange protocols, enabling automated cargo documentation that partially replaces their manual reporting processes. This collaborative approach allows Beta to co-create new capabilities without massive capital investment and gradually build internal AI readiness.

5.2.2 Value Co-Delivery Through AI-Enhanced Services

This stage focuses on improving existing value propositions through AI-enabled applications that enhance value delivery and operational efficiency. Central topics for this transformation revolve around the increasing demand for visibility, reliability and accountability from the different fronts of the industry, which traditional operations struggle to provide without technological improvements.

Starting with current value delivery assessment and further enhancement, this step focuses on the systematic evaluation of existing services capabilities, which is a vital precondition to identify opportunities for AI-enabled improvements (Kolagar, Parida, & Sjödin, 2022). Here **maritime service operators** must define what are their strategic priorities for driving innovation and improve the delivery of their value propositions, informed by the discovery of fitting AI-capabilities and guided by **digital transformation partners.** The latter help the former recognize what is technically feasible and discover digital value delivery opportunities (Kolagar, Parida, & Sjödin, 2022).

Furthermore, the delivery process strengthens customer relationships by improving the digital customer experience. This is a result of recognizing that **shipping services customers** increasingly expect transparency and real-time information access similar to other industries because of the digital servitization phenomena (Kolagar, Parida, & Sjödin, 2022). Thus, these decisions should be taken based on the feedback provided by customers. **Technology developers** support these customer-facing capabilities, developing AI-powered platforms that provide enhanced experiences, responsiveness and tolling support.

Additionally, collaborative service integration addresses the opportunity to enhance value delivery through coordinated services with ecosystem partners. This is supported by the suggestion of Favoretto et al. (2022) that digitalization increases the importance of customers and this makes companies more dependent on relational capital, meaning trust, communication, mutual learning and co-creation. **Port & infrastructure managers** are particularly recognized for their role in optimization of supply chain workflows (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024), enabling collaboration through integrated logistics platforms and shared data systems. The objective is to improve coordination with supply chain partners through better communication, service scheduling and data access, resulting in a reduction of perceived inefficiencies while maintaining operational independence.

As emphasized by the analysis, operational intelligence optimization is among the main drivers of AI-technology adoption. Otherwise called augmentation capabilities that leverage the power of AI to enhance human decision-making and productivity (Sjödin, Parida, & Kohtamäki, 2023). This phase focuses on using AI to improve decision-making that directly impact service quality and operational performance. For instance, **equipment and maintenance providers** can contribute significantly to this optimization process through AI-powered asset monitoring and predictive maintenance solutions that prevent equipment failure, ensuring consistent service delivery. Similarly, **maritime service operators** can also define the areas of focus required to improve their operational intelligence that can be developed in collaboration with a **digital transformation partner**. As a result, operational performance results drive continuous optimization across all the service delivery aspects.

This process repeats itself, driven by customers' expectations and competitive pressures that demand services enhancement and adaption. Initial service improvements generate customer feedback and market insights that update development priorities, leading to a continuous cycle of value refinement. This iterative dynamic is a reflection of the incremental innovation tendency observed in traditional industries that prioritize service improvement to maintain operational stability rather than disruptive innovation. Chen et al. (2021) further validate this perspective by describing the evolutionary nature of digital servitization, in which value delivery systems progressively expand from the internal operations to the supply and distribution chain and eventually to the broader ecosystem.

Building on the foundational capabilities established in the co-creation phase, Beta develops AI-enhanced services that directly address customer satisfactions while leveraging ecosystem partnerships. The consolidated data storage solution now enables Beta to offer real-time cargo tracking through a customer portal, replacing their previous periodic manual reports and communications with automated updated powered by the IoT sensors and tracking systems. Additionally, working with a sustainability enabler partner, Beta uses standardized fuel monitoring data to elaborate automated carbon footprint reports per shipment, directly addressing the growing demand for sustainability transparency while preparing for their 2026 CSRD requirements. Also, the Digital Operations Coordinator, now trained in AI applications, collaborates with the digital transformation partner to develop a predictive arrival time solution that uses weather data, vessel performance metrics, and port data, improving Beta's operational flexibility from an internal capability into a customer service offering. Moreover, through the port infrastructure collaboration, Beta co-delivers integrated logistics services by automating cargo documentation elaboration and transfer, reducing administrative burden and positioning Beta as a digitally integrated partner rather than just transport. These AI-enhanced services enable Beta to maintain their flexibility advantage while offering digital transparency and reliability that larger contracts require.

5.2.3 Value Co-Capture Through AI-Enabled Revenue Models

Here, emphasis is made on the required value capture for the continuous developments and sustained efforts in AI investments. This stems from the findings that companies need first to recoup the investment made in digital technologies to justify further development and expansion (Chen, Visnjic, Parida, & Zhang, 2021). In this context, the co-capture approach recognises that mechanisms for equitable benefit redistribution should be in place to support long-term collaboration. Failing to provide visibility and establishing fair redistribution methods to those stakeholders involved could undermine both future partnerships and the innovation ecosystem (Costabile, 2024).

Fundamentally, efficiency-based profit optimisation is concerned with using AI to reduce operational costs and improve asset utilization and resources efficiency, creating direct financial benefits that support continued technology investment (Favoretto, Mendesa, Oliveira, Cauchick-Miguel, & Coreynen, 2022). This can take the form of fuel consumption optimisation, reduced waiting times or reduced unplanned downtimes that generate measurable cost savings (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

Performance and compliance value integration addresses the opportunity to monetize AI-enabled performance improvements and compliance capabilities. In this regard, studies have described the use of digital platforms to monitor environmental conditions and reduce emissions (Favoretto, Mendesa, Oliveira, Cauchick-Miguel, & Coreynen, 2022; Sjödin, Parida, & Kohtamäki, 2023). **Sustainability & ESG enablers** can play an important role here by providing solutions that streamline the compliance process, supporting analysis and administrative work necessary to qualify for sustainability incentives.

Moreover, data monetization strategies explore opportunities to generate revenue from data products and services that can provide access to other industry players willing to pay a premium for them. Structured partnerships between **maritime service operators** and **technology developers** can help shape these new forms of revenue streams (Chen, Visnjic, Parida, & Zhang, 2021). This however requires a higher maturity in terms of technology adoption and strengthened infrastructure that ensures reliability and proven proof of concepts (Favoretto, Mendesa, Oliveira, Cauchick-Miguel, & Coreynen, 2022).

Subsequently, collaborative value refinement addresses the ongoing requirement for optimizing value capture through ecosystem partnerships and shared benefits arrangements. **Port & infrastructure managers** contribute to this refinement through coordinated optimisation initiatives that create shared value across the maritime value chain. This is particularly relevant as it's also recognised that industry players must be able to perceive the enhanced value and be given incentives to sustain uninterrupted collaboration (Kolagar, 2024). Moreover, literature also highlights the importance of alignment of role definitions during collaboration for securing the realization of new value propositions (Kolagar, Parida, & Sjödin, 2022).

The iterative nature of this dimension emerges from the exploratory approach required to identify optimal revenue models and pricing strategies for AI-enabled solutions. Initial monetization initiatives provide market feedback for continuous refinement and adaptation to the market. This iteration also supports the evolution from cost-savings focus to revenue-generating applications capabilities (Chen, Visnjic, Parida, & Zhang, 2021).

Beta's transition to AI-enabled value co-capture shows both promising early results and potential for increased benefits in the future. The real time cargo tracking system and customs documentation semi-automation already enable Beta to save time from customer service personnel, which can be capitalized by redirecting their time to more critical processes that often end up in extra expenses and reduce port turnaround time. This monitoring serves as the foundation for future AI-enabled route optimization algorithms that can deliver fuel and maintenance expenses. The automated carbon footprint reporting initially offers basic access to customers while Beta continues to explore what data on detailed emissions analytics would customer be willing to pay for. Ahead of 2026 CSRD compliance Beta can better elaborate feasible goals avoiding higher costs and processing time in the future. Other potential data monetization strategies can be explored while data maturity is still in development.

Collaborative value distributions with ecosystem partners evolves gradually as relationships mature and trust develops. For instance, the port collaboration and predictive arrival yields modest port surcharges reductions and improved scheduling predictability, while increased quality and speed of cargo documentation also reduce terminal surcharges and improve customs clearance times for customers. While potential for growth exists, Beta's current focus remains on solidifying these foundational revenue improvements and building operational confidence in their new digital capabilities before pursuing more complex value capture mechanisms.

5.3 Level 3: Sustainability Benefits Realization

The third layer illustrated in figure 5.4. encompasses the realization of benefits where AI-enabled business model innovation delivers measurable sustainable outcomes that reinforce the cycle of innovation. This level acknowledges that sustainability implies long term survival of the ecosystem and the organizations within it. However, there may exist paradoxical tensions between economic, environmental and social objectives (Abdelkafi, Pero, Masi, & Capurso, 2022; Sridhar & Jones, 2013). Therefore, these benefits must be integrated across economic, social and environmental components to create lasting competitive advantage and stakeholder value. In this context, servitization offers a suitable strategy to navigate these trade-offs and balance the three elements of the triple bottom line (Abdelkafi, Pero, Masi, & Capurso, 2022).

The basis of this process lies in the integration of economic sustainability for the recognition of tangible benefits. This element recognizes that operational adopters require clear financial benefits from investments into AI-driven applications as well as those aimed to produce social and environmental positive initiatives (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). This emphasizes to start by using AI to support the reduction of operational costs while achieving environmental objectives to strengthen continued commitment and expansion. Revenue generation opportunities can emerge after achieving adoption maturity that demonstrate superior outcomes due to AI-enhanced monitoring and optimization and through synergies with ecosystem player to secure ecosystem incentives and to produce innovative novel value capture mechanisms (Chen, Visnjic, Parida, & Zhang, 2021).

Figure 5.4. Framework - 3rd level: Sustainability benefits realization (Self - illustration)

Furthermore, social value creation addresses the human dimension of sustainable AI implementations which can be appreciated for example by contributing to workforce enhancement, safety improvements and ethical aware deployments (Abdelkafi, Pero, Masi, & Capurso, 2022). This recognizes that sustainability also involves social responsibility alongside economic and environmental objectives. For instance, education initiatives help industry professionals to adopt and adapt AI-applications to enhance their work rather than displacing people out of work. Therefore, appropriate change management is necessary to address workforce concerns and receive feedback necessary to ensure ethical AI developments (Di Vaio, Palladino, Hassan, & Escobar, 2020). Improved safety conditions through AI application also ensure uninterrupted operations and avoid situations that could impact the economic standing of the organization (Kolagar, 2024; Sjödin, Parida, & Kohtamäki, 2023).

Lastly, environmental impact optimization through AI-driven operational improvements should deliver measurable outcomes that satisfy regulatory requirements and strengthen competitive positioning. This process starts with the definition of critical environmental areas of focus to determine the direction of the initiative to be developed. Subsequently, operational efficiency improvements carried out such as optimization of routes, fuel efficiency and emissions monitoring provide the technical basis for performance optimization. For the realization of these benefits ecosystem-wide collaboration and feedback is necessary, as highlighted during the analysis chapter, these priorities are also driven and supported by ecosystem players that provide incentives, compliance guidelines and support the implementation (Sjödin, Parida, & Kohtamäki, 2023). However, this must be supported by the development of measurement and monitoring capabilities that enable organizations to monitor and justify environmental claims, investments and compliance reporting (Bressanelli, Saccani, & Perona, 2024).

The cyclical nature of this process as represented in figure 5.4. reflects the reinforcing nature of sustainability across its components highlighting their interdependence (Di Vaio, Palladino, Hassan, & Escobar, 2020). Economic sustainability provides the financial foundations for social and environmental initiatives (Abdelkafi, Pero, Masi, & Capurso, 2022), while social value creation builds organizational support for continued innovation (Di Vaio, Palladino, Hassan, & Escobar, 2020), and environmental impact optimization creates market advantages that enhance economic performance (Bressanelli, Saccani, & Perona, 2024). Moreover, this self-reinforcing cycle addresses the fundamental challenge of sustaining innovation momentum in traditional industries where short-term pressures often undermine long-term initiatives (Bressanelli, Saccani, & Perona, 2024). Thus, demonstrating integrated benefits across all sustainability dimensions creates compelling business cases for continued AI related investments and organizational support (Zechiel, Blaurock, Weber, Büttgen, & Coussement, 2024).

Beta's economic sustainability improves first through interconnected digital efficiency gains. Automated cargo documentation and real-time tracking can optimize administrative overhead, while improved turnaround times enhance vessel utilization rates, directly translating into margin gains. The predictive arrival and fuel monitoring systems can support efforts in fuel cost reduction through optimized voyage planning, which also brings environmental benefits. Additionally, carbon footprint monitoring allows Beta to access contracts that require these capabilities, providing business growth opportunities. On the social value creations side, working conditions improve as repetitive low value tasks are reduced and the crew member gain digital skills, enabling focus on higher value activities.

Environmental impact is optimized by potential emission reduction and resource usage improvements, but more importantly through accurate monitoring that can support future efforts. In preparation for CSRD compliance Beta can set feasible targets and use earlier compliance as a competitive advantage while competitor struggle with basic reporting. Nevertheless, full benefits remain partially constraint by ongoing operational scepticism and the need for continued change management. Furthermore, results and learnings from this iteration provide insights into the other layers for further improvement, readjustment of focus and create support for more ambitious projects. Addressing these learnings requires sustained commitment to digital capability development and ecosystem collaboration.

6 Conclusion, Implications and Recommendations

This chapter concludes the thesis by outlining its contribution to the literature and highlighting the key research and practical implications. Additionally, the limitations of the study and recommendations for future avenues of research are provided.

6.1 Conclusion

In this section, the main finding will be presented and three sub-questions answered. Subsequently, building on the previous answers, the conclusion to the main research questions is elaborated.

6.1.1 What characterizes the current business models within the shipping ecosystem?

Based on the findings of the interviews conducted, the ecosystem mapping and framework elaborations the current business model of the maritime-shipping industry is described. This is further corroborated by the desk research. The shipping ecosystem is characterized by several distinctive features that reflect what many interviewees described as “traditional”, currently facing mounting pressure for digital and sustainable transformation.

A. Value Creation Characteristics

Traditionally, the shipping industry operates under the port-to-port model, with quality of the service as the main differentiator among competitors (Bravos, 2018). This operation is supported by heavy employment of physical assets, mainly vessels, but also port and terminal infrastructure and equipment necessary to handle cargo in and out of the vessels. Moreover, these assets possess an extended lifecycle of around 20 years (United Nations Conference on Trade and Development, 2024); thus, not always ready for adoption of emerging technologies. In this regard, strategic decision-making is often faced with significant capital requirements for long-term investments (Fiksdahl & Wamstad, 2016). This financial burden limits flexibility for riskier investments such as AI infrastructure or decarbonization initiatives (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

The ecosystem also prioritizes safety as a critical factor to ensure service reliability and avoid environmental damage (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). This conservative approach stems from the safety-critical nature of maritime operations and the substantial costs associated with failures such as interrupted operations; increased expenditure; social and environmental obligations; as well as reputational damage (United Nations Conference on Trade and Development, 2024). Thus, creating a risk-averse culture that favours proven solutions over experimental technologies (Fiksdahl & Wamstad, 2016).

One characteristic is the fragmentation of the value chain structure where different stakeholders with specialized roles operate even within the same physical limits of the vessel. This creates many levels of operational activities that need to be coordinated in order to deliver value (González Chávez, et al., 2024). Commuting this stratification with the required integration of data for increased operational visibility and the necessary skilled labour proves to be a major challenge for digital servitization (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024).

Limited collaboration patterns, the ecosystem is marked by transactional relationships, where value exchange is prioritized over long-term collaboration (Fiksdahl & Wamstad, 2016). Operational optimization occurs in silos, here each stakeholder focuses on their own efficiency improvements rather than coordination system-wide performance enhancement (Bravos, 2018). Technology and digital transformation partners functions mainly as external service providers often far from core value creations processes with maritime operators conducting short-term collaborations and acquisitions as means of innovation rather than long-term partnerships (Fiksdahl & Wamstad, 2016). Conversely, port authorities are perceived as capable of driving ecosystem-wide integration and standardization (Bravos, 2018).

B. Value Delivery Characteristics

The core business revolves around the provision of cargo transportation services, often described as the backbone of global trade, it faces mounting pressure to prioritize reliability, safety and cost efficiency to ensure customer satisfactions. In this regard, ecosystem actors focus their activities on fundamentally ensuring uninterrupted operations (United Nations Conference on Trade and Development, 2024). This is supported by the complex web of national and international regulations (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024) that enforce compliance with formal agreements supported by widely accepted legal structures that regulate the scope of the service and determine responsibilities (González Chávez, et al., 2024).

From the interviews, it was also highlighted that customer visibility is often limited, and real-time monitoring is a constraint (Bravos, 2018). This is in part influenced by the dominance of legacy systems, outdated information infrastructure and restricted connectivity especially at sea (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024). Therefore, customers have to interact directly with service providers for accessing information rather than employing integrated digital platforms. And in more complex networks like those of port authorities, too many service providers create data silos that complicate the integration of the value chain (González Chávez, et al., 2024).

The intense competition drives carriers to constantly improve efficiency and lower costs (Lin & Huang, 2013) to maintain their market position and attract price-conscious customers (Fiksdahl & Wamstad, 2016). For instance, strategies like the of use of increasingly large vessels to achieve economies of scale enhances service frequency and improves fuel consumption. This drives maritime services operators to provide standard shipping services in a highly competitive environment (Fiksdahl & Wamstad, 2016). Which leads to high levels of specialization in service offerings and limited customization opportunities.

Furthermore, this standardization and efficiency drive are shaped by the substantial investments made on assets such as ships. Theses long lifecycles require the establishment of long-term relationships with various ecosystem actors such as equipment and maintenance providers to ensure continuous operation, creating a lock-in effect (Fiksdahl & Wamstad, 2016). This dependency is further reinforced by the high costs and complexities required to upgrade older equipment or switching providers (González Chávez, et al., 2024).

C. Value Capture Characteristics

Historically, the shipping industry value capture mechanisms focus on efficient movement of goods and maximizing cargo capacity. In this regard, the primary source of revenue are freight rates, which are influenced by market cycles with pronounced periods of growth, falling rates and recovery (Bravos, 2018). For maritime firms, the cyclical nature of the industry constantly challenges profit objectives (Fiksdahl & Wamstad, 2016). While major players use strategies aimed at creating economies of scale by acquiring large vessels; smaller companies struggle to stay competitive (Lin & Huang, 2013).

Customer decisions are price-driven, which create a cost competitive environment in order to improve margins (Fiksdahl & Wamstad, 2016). This is extrapolated to commercial relationships with complementary services in the ecosystem. Thus, despite the potential benefits of new technologies, companies often struggle with budget constraints (OPEX and CAPEX), and fearful of unsuccessful investments with long capitalization periods (González Chávez, et al., 2024). This directly affects the willingness to invest in the development of capabilities necessary to create new revenue opportunities from data products or services.

Price competition and highly standardized services also limit opportunities for the emergence of differentiation through premium offerings (Fiksdahl & Wamstad, 2016). This is corroborated by some interviews that mention limit interest from customers on solutions that provide enhanced environmental performance or sophisticated technological solutions. However, the economic climate still generates pressure toward innovation that is often directed to produce cost-saving solutions (Fiksdahl & Wamstad, 2016).

Sustainability and ESG goals are primarily compliance-focused (González Chávez, et al., 2024); thus, often seen as a financial burden instead of a value capture opportunity. For instance, the EU ETS and IMO's Carbon Intensity Indicator are expected to increase operating costs that are likely to be transferred to customers through higher freight rates (United Nations Conference on Trade and Development, 2024), this was also corroborated by some interviews in which specific fees for operations within the EU were mentioned.

6.1.2 How AI-driven technologies can impact value creation, delivery and capture in the shipping ecosystem?

Through the elaboration of this analysis, it has been highlighted that the maritime shipping industry stands at a critical moment where the traditional model is challenged by mounting external pressure including the cross industries influence of digital servitization. This research elaborated on how AI-driven technologies not merely serve as an operational tool but also reshape the value structures of the shipping ecosystem's business model. Additionally, this transformation occurs through iterative cycles where initial outcomes generate insights that inform subsequent developments in multiple levels of business model innovation, creating compounding transformational effects.

A. Value Co-Creation Through AI and Collaboration

The research demonstrates that value creation shifts from individual efficiency optimization to ecosystem-wide capability development, where shipping companies, technology partners, equipment providers, port and infrastructure authorities shape the value co-creation process for AI adoption.

This transition involves four critical mechanisms: organizational AI awareness and capabilities development, that builds cross-departmental understanding of the technology and capabilities internal capabilities for its use; strategic AI technology selection and implementation, which aligns with operational and strategic requirements; data infrastructure development, that captures and transforms operational data into a strategic asset; and strategic partnership optimization and collaborative refinement to leverage external expertise while building a more resilient internal structure.

These findings reveal that successful AI adoption requires companies to develop new organizational capabilities and conduct change management necessary to deal with cultural resistance while preserving industry-specific expertise. Specific roles in the industry can support this and provide guidance in strategic decision-making. This should be followed by the set-up of robust data infrastructure that supports the development of these strategic capabilities. And the collaborative approach enables access to critical capabilities need for guidance during this process. These steps repeat themselves as more sophisticated efforts are pursued and inform other layers of the innovation process.

B. Value Co-Delivery Through AI-Enhanced Services

As previously stated, the most potential is observed in using AI for enhancing existing service capabilities while enabling new forms of customer engagement and operational excellence.

The analysis identifies four key dimensions for service co-delivery: current value delivery assessment and enhancement, where companies evaluate core value propositions to prioritize for optimization; digital customer experience integration that addresses growing demands for transparency and real-time information access; collaborative service integration that supports coordination through data sharing solutions and standardized communication protocols; and operational intelligence optimization that improve decision-making capabilities while preserving human expertise in critical operations.

The enhancement first approach emphasizes the risk averse nature of the industry and the preference for proven solutions to ensure reliability, positioning AI as an augmentation technology rather than replacing existing practices. Port authorities emerge as a critical enabler for ecosystem wide services integration due to their institutional standing to facilitate standardization and enable collaboration.

C. Value Co-Capture Through AI-Enabled Revenue Models

AI-enable value capture mechanisms transform operational efficiency into sustainable competitive advantage and novel revenue streams.

Here four value capture pathways are theorized: efficiency-based profit optimization, through operational cost savings that deliver relevant ROI, such as fuel consumption reduction; performance and compliance value integration, that ensures regulatory requirements are met, and competitive advantage is achieved through superior monitoring and reporting; data monetization strategies, providing novel revenue stream avenues from operational insights valuable for the ecosystem; and collaborative value refinement, through the establishment of benefit distribution mechanisms that incentivize continuous collaboration (González Chávez, et al., 2024).

Findings support the conclusion that clear measurable outcomes are required, primarily in the form of financial incentives, as the industry operates under intense cost optimization pressures and cannot sustain initiatives that compromise long-term viability. However, the research also reveals that AI creates opportunities for capitalization of social and environmental responsible services and to access financial incentives from financial institutions and authorities that value environmental performance. Measurable positive outcomes on this level drive further iterations on all the levels of business model innovation. This coupled with technological maturity can support the progression from cost-savings focus to revenue-generating applications.

6.1.3 What are the sustainability benefits of adopting AI-driven technologies?

Literature as well as the analysis conducted agree that the intersection of artificial intelligence and sustainability provide powerful opportunities for using technological innovation in favour of economic, social and environmental benefits. This research shows that AI-driven technologies have the potential to produce reinforcing forces across the "triple bottom line"; not without addressing clear trade-offs (González Chávez, et al., 2024), which are essential for an industry under pressure to meet ambitious net-zero targets by 2050 and increasing accountability while remaining economically viable.

Firstly, Economic sustainability in the maritime sector focuses on converting operational efficiencies into tangible financial gains that support ongoing investments in social and environmental responsible practices. This research shows that shipping companies can best benefit from solutions that target fuel optimization, predictive maintenance, route planning and alternative energy sources management, which not only reduce emission, but also costs and minimize downtime. Furthermore, developing AI capabilities facilitates access to financial incentives, such as green financing and environmental performance benefits, while ensuring readiness for securing premium pricing for environmentally responsible services. This is in line with "clear business case" paradigm strongly emphasized during the analysis to justify further investments in innovation.

Secondly, Social sustainability in shipping emphasizes workforce capabilities enhancing, safety conditions improvement and ethical implementations. Findings highlight that the industry culture prioritizes safe work condition through risk detection systems to ensure uninterrupted operations. Similarly, workforce upskilling positioning AI as a tool for augmentations rather than replacement fosters responsible deployment but also supports adoption. This approach not only addresses internal concerns like job security but also responds to growing external demands for social responsibility from the authorities and customers.

Lastly, environmental sustainability in the maritime shipping sector focuses on reducing emissions and enhanced regulatory compliance. However, due to the stratified nature of the operations, ecosystem-wide coordination is required to achieve overall environmental goals. This study shows that AI can contribute to emission reduction through resources and operations optimization, improved port scheduling and emissions monitoring systems. Through the findings, it is also widely emphasized that this needs support from an evolving data infrastructure that provides measurable outcomes, as well as the establishment of data sharing mechanisms. Additional, as mentioned in the literature (Durlik, Miller, Kostecka, Łobodzińska, & Kosteck, 2024; González Chávez, et al., 2024) as well as during the interviews, previous attempts of technology implementations to address environmental goals fall short due to lack of data that supports the expected results; thus addressing these gaps is essential. Ultimately, it is concluded that AI can support reinforcing cycles where environmental, social, and operational gains drive improvements across the triple bottom line.

6.1.4 Main Research questions: How can AI-driven technologies drive sustainable business model innovation within the shipping ecosystem in the Netherlands?

To conclude, AI-driven technologies drive sustainable business model innovation within the Dutch ecosystem through a systematic three-level transformations process that fundamentally reshapes value creation, delivery and capture mechanisms across the different levels of stakeholders' interactions. The research demonstrates that successful AI-driven sustainable innovation begins with comprehensive business model analysis that evaluates current organization readiness, in terms of culture, information infrastructure, market position and strategic priorities specific to the traditional industry. This foundation supports the progression to iterative cycles of business model innovation, where AI technologies serve as a catalyst for collaborative value co-creation with ecosystem partners. The Dutch context proves to be adequate for this transformation due to the established regulatory frameworks, infrastructure, and concentration of maritime industry knowledge that facilitates cooperations and knowledge sharing.

Sustainability benefits in this industry takes the form of economic viability, social responsibility, and environmental responsibility that can be integrated into value propositions rather than standalone solutions. The pursuit of operational efficiency improvements that reduce resources consumption and promotes optimal coordination prove to be satisfactory opportunities for AI adoption. The iterative approach emphasized in the framework emerges from the acknowledgement that industry-wide resistance to change must be addressed and continuous refinement cycles should inform subsequent developments while building trust for enhanced cooperations.

6.2 Contributions to Academic Literature

The research makes significant theoretical contributions to advance knowledge at the intersection of digital servitization, sustainability and AI adoption in traditional industries such as shipping. Although the study focused on organizations in the Dutch Market operating mainly in Western Europe, it is expected that findings are generalizable to the maritime-shipping sector in other regions and industries with similar dynamics such as fragmentations and conservativeness as discussed by the interviewees (González Chávez, et al., 2024).

To begin, the study provides a comprehensive framework to integrate AI technologies with sustainable business model innovation, specifically in the maritime ecosystem. The three-level framework contributes to business model innovation and servitization theory by providing an implementation guideline and archetypes to support maritime shipping companies in this transition (González Chávez, et al., 2024). Making a strong emphasis on business model iterative assessment as a prerequisite for successful adoption, thus challenging technology-first approaches.

Moreover, this research also furthers ecosystem orchestration theory by focusing on the collaborative nature of AI enabled sustainable innovation in fragmented value chains. While some studies take the perspective of the role of dominant orchestrators (Kolagar, 2024) or a focal-firm perspective (Chen, Visnjic, Parida, & Zhang, 2021), this research takes the ecosystem perspective to cover a broad view on the efforts made by multiple actors to co-create value through distributes collaboration mechanisms, this study directly addressed the call for role clarification relevant for increased collaboration (González Chávez, et al., 2024). These findings contribute to the understanding of collaborations and orchestrations in industries where actors don't usually possess sufficient resources or authority to drive wide-transformational processes.

The study addresses the gap in the literature about the role of AI technologies in digital servitization for sustainable innovation and its implications in the maritime industry (González Chávez, et al., 2024). A clear emphasis is made on the impact on economic, social, and environmental sustainability providing grounded evidence of the recognized urgency, moving beyond theoretical conceptualizations of triple bottom line integrations and providing practical mechanisms for achieving sustainability benefits including economic and social aspects (Abdelkafi, Pero, Masi, & Capurso, 2022).

Furthermore, in comparison to existing studies in business model innovation, digital servitization and sustainability that predominantly focus on manufacturing companies (Kolagar, 2024; Abdelkafi et al., 2022; Sjödin et al., 2023), this research examines an asset-intensive, service-oriented industry characterized by substantial capital requirements, extended asset lifecycles, and restricted profit margins (González Chávez, et al., 2024). This maritime context provided a distinct perspective on digital transformations challenges, particularly regarding risk aversion, legacy infrastructure constraints, and the need for ecosystem-wide collaborations to support technological investment, insights that are applicable to across other industries (González Chávez, et al., 2024). In addition, the inclusions of companies of different sizes ranging from start-ups to established corporations enhances the diversity of perspectives of this study (Kolagar, 2024).

Methodologically, the research demonstrates how grounded theory approaches can generate industry-specific insights that inform both theoretical development and practical applications, based on the application of the Gioia methodology for nascent theory development. In this regard, contributed to the limited body of research on AI adoption, Ecosystem Orchestration, and Digital Servitization in the maritime industry as shown in figure 2.2, providing foundational insights that can inform future quantitative studies and longitudinal investigations of technology adoption patterns.

The table 6.1. provides a summary of some of the theoretical contributions of the AI-SBMI framework relative to existing frameworks that commute business model innovation with sustainability outcomes in industrial contexts.

Table 6.1. Contribution of the AI-SBMI framework to business model innovation implementation frameworks

Framework	Focus	Limitation	AI-SBMI contribution
Triple Layer Business Model Canvas (TLBMC) **(Joyce & Paquin, 2016)**	Integrates economic, environmental, and social concerns into a holistic view of an organization's business model. It supports development, visualization, and communication of sustainable business model innovation	Designed as a universal tool, it can be too generic or overwhelming at first to use. It's a high-level, integrated and holistic perspective of the entire business model Its vertical coherence provides clear connections across the TBL but not the reciprocal effect of economic, social and environmental elements.	Process built framework focused on ‘conservative’ yet globally relevant industries. In detail exploration of tangible objectives of industry players such as economic value, compliance and AI technologies adoption. Frames value innovation and sustainable benefit creation as a mutually reinforcing and collaborative process
Digital servitization through business model **(Chen, Visnjic, Parida, & Zhang, 2021)**	Depicts how a traditional manufacturer implements digital servitization through business model expansion next to the adoption of digital technology generalized from a real case scenario. Presents a 3 stages approach to the evolution value capture mechanisms from efficiency base to new sources of revenue	Tailored for manufacturing companies. Sustainability is mentioned as an outcome but not systematically integrated. Assumes organizations are ready for transformation. Focuses primarily on focal firm perspective with ecosystem collaboration mainly occurring at the third stage.	AI-SBMI addresses organizational readiness challenges as a foundation before going into technology adoption and BMI. Sustainability is ingrained as part of the transformative process from the start. AI-SBMI presents a cyclical, iterative approach adding to the continuous perspective of BMI Presents collaborative value innovation mechanisms from the beginning.

	Describes how digital technology commutes continuous and discontinuous elements of business model innovation.		
Multi-level framework for orchestrating the ecosystem in digital servitization **(Kolagar, 2024)**	Transportation and logistics ecosystem focus, with manufacturing firms as a primary orchestrator Co-creation of data-driven digital services and solutions to drive sustainable industry benefits. Describes how main orchestrators should carry out orchestration starting from the individual level through the organizational and ecosystem level elaborately interconnected that co-evolve to generate sustainable benefits.	Drivers of sustainability benefits pursue such as compliance or safety are not addressed. Motivations for digital servitization are implicit rather than explicitly examined. Technology infrastructure evaluation for data-drive solution in initial stages can be further explored	Pressure analysis such as regulatory, competition and financial pressures are addressed as drivers of digital servitization and sustainability efforts. Enriches the analysis of the individual, organizational and ecosystem levels for BMI. Expands ecosystem orchestration theory from alternative perspectives to the main orchestrator Reveal the potential of port authorities as critical coordination hub, despite not being the primary value creators.

6.3 Practical Implications

Regarding practical implications, the research provides guidance for decision-makers in the maritime industry navigating the complex intersection of AI adoption and sustainability requirements. The three-level framework offers a structured approach for decision-makers to assess current state of readiness, AI-driven technologies selection and implementations, and realize sustainable benefits while maintaining operational stability and financial performance.

Moreover, the study also emphasizes the importance of conducting comprehensive business model assessments before pursuing AI initiatives, highlighting how legacy infrastructure constraints, organizational culture, and market positioning can influence technology adoption. Following this, managers would make informed efforts towards building foundational capabilities such as organizational change management, data infrastructure, and strategic partnerships before selecting and implementing AI applications. In this regard, organizations can employ the proposed framework as a tool for continuous assessments and execution of their AI adoption efforts.

Furthermore, strategic guidance is provided for developing sustainable competitive advantage through AI-enabled business model innovation. Operational adopters can leverage value co-creation, co-delivery, and co-capture stages to identify areas where AI investments will deliver relevant returns while pursuing sustainability objectives. Emphasis is made on collaborative innovation that managers should prioritize over purely internal technology development. For this, the roles of different actors are highlighted to act as guidance when looking for proper partnerships. Nevertheless, the findings also position port authorities in a particular stance for enabling critical industry-wide collaboration, suggesting opportunities for public-private partnerships and benefits distribution mechanisms that accelerate AI adoption, compliance, and sustainability.

For technology providers and consultants aiding the maritime industry, a clear emphasis is made on understanding industry-specific constraints and opportunities to enhance operational practices first, rather than focusing on disruptive value propositions. As concluded, solutions that keep humans in the loop and provide augmented decision-making offer guidance for developing clear and feasible solutions. For this, ROI achievement through operational efficiency improvements, regulatory compliance and sustainability incentives is recommended, while supported by data infrastructure that allows measurement and monitoring over time.

The research reveals that each role contributes with distinct capabilities and benefit from shared value creation. The following table 6.2. summarizes actionable guidance for each of the nine ecosystem roles identified, emphasizing collaborative approaches and shared benefit mechanisms that enable sustainable AI adoption while maintaining operational stability and competitive advantage.

Table 6.2. Practical implication of the framework per ecosystem role

Ecosystem Role	Practical Implications from AI-SBMI Framework
Maritime Services Operators	Conduct comprehensive business model assessment before AI adoption; prioritize clear ROI capture opportunities such as fuel optimization and predictive maintenance; develop internal AI capabilities through strategic partnerships; ensure data availability for sustainability related efforts
Port & Infrastructure Managers	Lead ecosystem-wide standardization of communication protocols; facilitate cross-stakeholder data sharing; provide sustainability incentives for efficient operations
Technology Developers	Design maritime-specific AI solutions that augment rather than replace human expertise; focus on interoperability with legacy systems; develop modular, scalable implementations
Digital Transformation Partners	Guide organizational change management and cultural transformation; provide strategic technology selection support; bridge technical knowledge gaps in conservative industry; manage implementation pace to minimize workforce resistance; get involved with Knowledge & Innovation Partners to understand maritime-specific business cases and value co-capture opportunities.
Knowledge & Innovation Partners	Establish knowledge transfer mechanisms between research institutions and industry; set up shared data repositories for industry-wide learning; facilitate industry-wide knowledge sharing from other roles' AI adoption experiences
Equipment & Maintenance Providers	Integrate data collection capabilities into maritime equipment; support assets connectivity through shared investments; integrate with customers' existing data capture capabilities
Sustainability & ESG Enablers	Provide sustainability performance tracking systems; promote standardized measurement frameworks for ecosystem-wide sustainability assessment; support transparency platforms that benefit entire supply chains
Shipping Services Customers	Provide feedback for customer-centric AI applications; participate in joint optimization initiatives for emissions reduction; collaborate in data sharing initiatives for supply chain optimization; support collaborative value capture mechanisms through shared benefits arrangements;
Financial Institutions	Develop green financing mechanisms tied to AI-driven sustainability performance; establish cost-sharing mechanisms for cross-organizational AI infrastructure investments; provide financial incentives for data sharing and collaborative optimization;

6.4 Limitations and Future Research

Although this research provides relevant findings into the role of AI technologies in driving sustainable business model innovation within the maritime shipping industry, it also presents certain limitations and opens avenues for future research.

First, the study's geographical scope presents important limitations that may affect the generalizability of findings. The research involved interviewees with representatives from Western European companies operating in the Dutch Market, which may limit the applicability of results to other regions with different regulatory environments, digital maturity levels, or supporting infrastructure. The selection of companies may not adequately reflect the diverse challenges and opportunities present in other regions. While findings are expected to remain valid outside the region of analysis, variations in regulations, business practices, and cultural approaches to technology adoption may still limit the transferability of results to other maritime markets worldwide. Therefore, to help validate the transferability of findings, expanding the scope to include case studies conducted in other geographical regions operating under different circumstances could prove beneficial.

Second, although extensive, the sample selection may impact the conclusions. For instance, the shipping companies involved in the research belong to a subset of the industry dedicated primarily to bulk shipping, which can present fundamentally different operational challenges, requirements, and technological needs compared to those involved in containerized shipping, or other specialized maritime segments; thus, further explorations could include these segments. Additionally, to ensure familiarity with the topics of discussion the companies selected already demonstrated interest and knowledge of digital technologies and AI systems, which might reflect a perspective that differs significantly from less digitized or more sceptical stakeholders in the industry. This potential bias is further exemplified by the reality that investment limitations are particularly challenging for smaller players in the industry, who often lack the resources to upgrade their equipment and invest in digitalization. Their inclusion could capture a more comprehensive view of industry perspectives and barriers to adoption.

Third, continuing with the sample selection criteria, a potential bias is created towards more successful or receptive adopters. This study may not capture the full spectrum of adoption experiences, particularly the challenges and barriers faced by companies that have attempted but failed at digital servitization, or those that have not chosen to pursue such initiatives altogether. This constrains understanding of the critical failure modes, organizations obstacles, and contextual factors that lead to unsuccessful digital transformations attempts in the maritime industry. Therefore, as recommended by Kolagar (2024) and Chen et al. (2021), promising research directions could focus on comparing successful technology adoption with documented failure cases, thus providing more nuanced guidance on when or how to pursue these initiatives. Additionally, this failure patters could be compared to those of industries with similar characteristics to develop a more robust and risk-ware theoretical framework also applicable across similar contexts.

Fourth, this research acknowledges that a significant methodological limitation inherent to qualitative thematic analysis is the subjective nature of data analysis, as described in Gioia et al. (2013), the act of coding is interpretative and creative process and researchers assume they are knowledgeable enough to figure out patterns in the data and make concepts and relationships surface that might escape the awareness of the informants. This subjective aspect introduced potential researcher bias in the thematic coding process, despite the application of the Gioia methodology. This limitation becomes particularly pronounced when considering that the maritime industry applies technical terminology that requires significant domain knowledge for accurate interpretation. Future research could combine qualitative insights with quantitative data assuming a mix-method approach, to check interpretation of qualitative data and to strengthen confidence in conclusions when data types converge (Edmondson & McManus, 2007). Since qualitative methods results can be further validated using quantitative methods such as fuzzy-based approaches (Kolagar, Parida, & Sjödin, 2024; Pappas & Woodside, 2021) and approaches based on multiple criteria decision-making techniques (Kolagar, Hosseini, & Felegari, 2021).

Fifth, the research design itself presents certain limitations that may affect the depth and long-term validity of the conclusions. The study employed a cross-sectional design to provide a broader perspective by including multiple stakeholders rather than focusing in-depth analysis of individual companies and their transformation journeys over time. This approach limits the ability to understand the nuanced processes and challenges that individual organizations face during digital servitization implementation. Also, certain important stakeholder groups, such as governmental and international organizations were not available for interviews, potentially missing crucial regulatory and policy perspectives that significantly influence digital transformation in the sector.

Sixth, the study takes place at a moment of low adoption and maturity of digital servitization and AI technologies in the maritime shipping industry, which means that findings reflect early-stage perspectives and challenges rather than mature implementation experiences. Future research could focus on longitudinal approaches that capture the evolution of digital servitization in the maritime industry over time and assess how companies' attitudes and implementation strategies evolve from the current stages of hesitance to mature adoption.

Seventh, the research focuses mainly on the technological perspective of digital servitization, resulting in less comprehensive analysis of other critical cultural, social, and organizational dimensions of innovation that are equally important for successful transformation which should be further explored. For instance, the role of politics, power dynamics, and competing interests that often significantly influence digital transformation initiatives in practice were not explored.

Finally, the complex trade-offs between economic, environmental, and social dimensions of sustainability require more detailed analysis to understand how organizations can effectively balance these competing priorities. Moreover, there exist nascent concerns about the environmental implications of using AI models in themselves for sustainability, and these environmental costs should be further explored and compared against the sustainability gains achieved through applied AI solutions. Further exploration, supported by data availability, could explore the environmental footprint of digital infrastructure itself and compare these costs against sustainability benefits achieved through digital servitization solutions.

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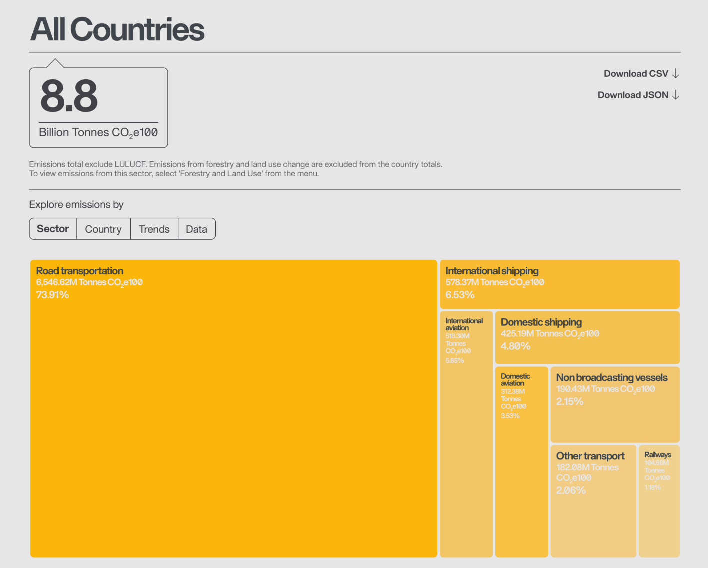
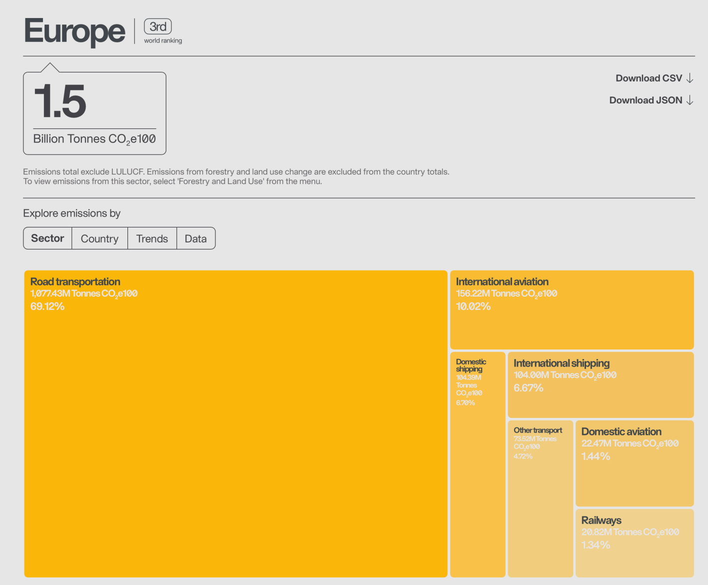
Appendix A: Distribution of CO2e emissions in Transport by sub sector 2023

Subsector distribution of global CO2e (CO2 equivalent) emissions of transport 2023 (Climate TRACE, 2024).



Subsector distribution of European CO2e (CO2 equivalent) emissions of transport 2023 (Climate TRACE, 2024).



Source: Climate TRACE. (2024). Emissions Map: Country inventory by Sector [CO_2e (100-year GWP), 2023 and 2024 data. Retrieved March 2025, from: https://climatetrace.org/inventory?sector=transportation&year_from=2023&year_to=2023&gas=co2e100

Appendix B: Interview protocol

Opening statement:
Thank you for taking the time to speak with me today. The objective of this study is to understand your perspective on AI implementation efforts, sustainability goals, implementation challenges, and business model innovation. When discussing these topics please keep in mind any experiences related to AI-driven projects you have worked on or are currently involved in within your organization, so please feel free to share any examples and observations you find interesting.

SECTION: Opening and Context

Concept to address	Question	Purpose	Priority
Interviewees Role	Could you describe your current role in the organization?	Establish rapport and understand the interviewee's responsibilities.	High
Main Activities	What are the main activities your organization focuses on in the shipping industry?	Understand the organizational context, without mentioning strategic goals to avoid resistance to disclose information.	High
Key Strategic Priority	What do you consider to be your organization's most important priority at the moment?	Identify a single strategic priority before moving to more detailed topics.	Medium

SECTION: The Business Model
In this section we discuss some aspects of the business model of your organization. We will use some concepts such as value creation, value delivery and value capture.
Value creation: refers to the benefit that a company's products or services provide to customers, often measured by the utility or satisfaction they derive.
Value delivery: involves everything necessary to ensure every paying customer is a happy customer: order processing, inventory management, delivery/fulfillment, troubleshooting, customer support, etc.
Value capture: is the process of converting that created value into profit for the company, typically through pricing strategies and market positioning.

Concept to address	Question	Purpose	Priority
Value Creation	How does your organization create value (i.e. create useful or positive outcomes) in the shipping industry?	Explore value creation without addressing concepts like delivery or capture.	High
Value Delivery	In what ways do you deliver this value to your customers or stakeholders? (ensure these outcomes reach your customers or other stakeholders)	Focus on the methods and channels of delivering value, separate from creation.	High
Value Capture	How does your organization capture value (i.e. benefit or earn revenue) from the products or services you provide?	Examine revenue or benefit mechanisms independently from creation and delivery.	High
Servitization	In your current business model, how do service-based offerings fit alongside traditional product offerings?	Understand the extent of servitization in the existing model.	Medium
Impact of AI on value co-creation	Have you observed any shift in customer demand or market positioning related to adopting AI-driven practices?	Examines if AI-enabled initiatives create tangible brand or competitive advantages.	High

SECTION: AI-Driven Technologies

In this section we discuss the usage of AI technologies and their impact on digitalization and moreover on what is known as "servitization". On one side, servitization uses digital technologies to better understand customers' needs and processes, to collect and exchange data, and to improve their service offerings. On the other hand, digitalization impulses companies to offer smart products, digitally enabled services, and digital solutions.

Concept to address	Question	Purpose	Priority
Examples of AI Projects	Could you share an example of an AI-related project or initiative that you think could fit within your organization?	Gather concrete instances of AI adoption, pilot programs or potential projects.	High
Motivation for Adopting AI	What motivates your organization to explore or implement AI solutions?	Understand drivers behind AI adoption (financial, strategic, or operational) without listing them.	Medium

Challenges in AI Implementation	What are the main challenges or barriers you have experienced, or you think could affect the implementation of AI in your organization?	Focus on barriers of adoption with an exploratory focus.	High
Servitization for product enhancement	To what extent do you integrate smart or connected features into your products to support additional services (i.e. digital servitization)?	Investigate how AI/digitalization transforms products into platforms for services. An activity related to the phenomenon called digital-servitization.	Medium
Servitization for new offerings	Are you using AI or other digital technologies to develop or improve any service-based solutions?	Connect AI adoption with the move toward servitization	Low
Outlook of the business model	What changes do you anticipate in the way of running your business (i.e. the business model) within the industry due to AI?	Focus on business model evolution as a separate concept.	High

SECTION: Ecosystem and Collaboration
As a recurring phenomenon in today's business environment, many innovation efforts are carried in collaboration with other players within the industry. These partners are sought for their expertise but also for their capabilities and services they provide to support the development of the industry.

Concept to address	Question	Purpose	Priority
Perception of the role	What would you call the role of your company in the industry/ecosystem?	Explore self-perception of their own role in the industry. To develop and informed nomenclature of roles.	High
Role of External Partners	What external partners or collaborations do you consider most relevant for AI initiatives?	Exploring collaboration priorities for AI without blending in broader strategic topics.	High
Impact of Partnerships	What impact do these partnerships have on the implementation or success of AI projects?	Understand how collaborations shape AI outcomes, distinct from general ecosystem readiness.	Medium

Ecosystem Readiness	How would you describe the shipping industry readiness for AI-driven collaboration?	Understand the broader ecosystem perspective.	High
Future of AI in Shipping	How do you think AI could mostly impact the shipping industry in the next few years?	Evoke forward-looking insights without mentioning sustainability or business model changes.	Medium

SECTION: Sustainability
Here we discuss the role of sustainability in your organization and, more importantly, its relation to AI technologies.

Concept to address	Question	Purpose	Priority
Defining Sustainability Goals	How does your organization define its sustainability goals in the shipping context?	Clarify sustainability ambitions as a standalone topic.	High
AI impact on sustainability	From your perspective, what sustainability benefits (environmental, social, or economic) do AI-driven technologies bring to shipping operations or the maritime industry in general?	Explore how AI can promote sustainable outcomes.	High
Opportunities at the Intersection of AI and Sustainability	What future opportunities do you see at the intersection of AI technologies and sustainability?	Explore potential synergies, distinct from immediate implementation issues.	Low
Impact of Sustainability on AI challenges	What do you think are the challenges to implement AI-based solutions aiming to meet sustainability goals?	Identify barriers and constraints in aligning digital servitization with sustainability. Also validate if some of the challenges before mentioned are impacted by including the sustainability aspect.	Medium

SECTION: Conclusion

Concept to address	Question	Purpose	Priority
Additional Points	Is there anything else you would like to add regarding AI, sustainability, or business model innovation that we haven't covered?	Open invitation for final thoughts.	High
Potential participants	Is there anyone in your organization you think I can get in touch with	Increasing opportunities to reach other employees within the organization.	High
Follow-Up Permission	May I contact you later if I have further questions or clarifications?	Clousure of the interview and maintain a connection for any follow-up.	Medium

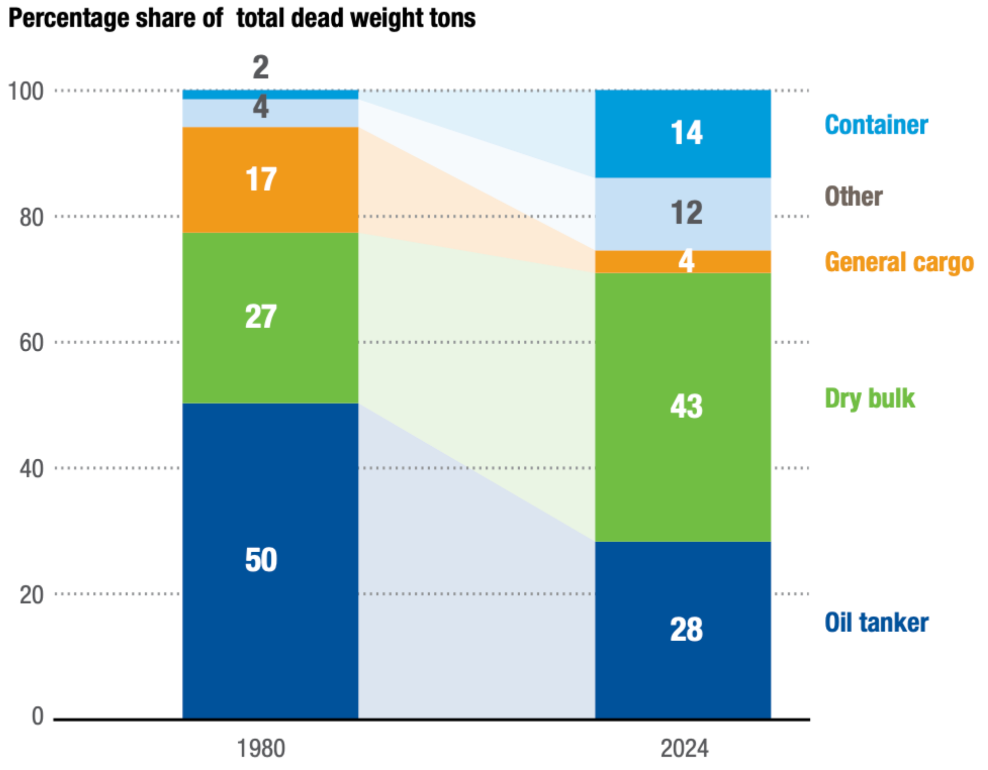
Thank you for your collaboration with your valuable insights and time dedicated to supporting this research.

Appendix C: The shares of various ship types in the world fleet capacity,

As indicate in the review of maritime transport 2024, figure II.3 (United Nations Conference on Trade and Development, 2024)

Figure II. 3

The shares of various ship types in the world fleet capacity, 1980 and 2024



Source: UNCTAD calculations, based on data from table II.1 of this report and UNCTAD statistics.

Source: United Nations Conference on Trade and Development. (2024). Review of maritime transport 2024: Navigating maritime chokepoints (UNCTAD/RMT/2024). United Nations Publications, https://unctad.org/system/files/official-document/rmt2024_en.pdf

Appendix D: Explicit quotations about the role of ports in the industry

Interview	Quotation
Interview 06	You know, a lot of activities happen when the ship is in port, right? The ship is moored and then somebody comes on board to inspect the tanks and to take samples, and everything is recorded by the captain and it will put that in.
Interview 12	I hope there would be a kind of planning mechanism that uses AI to actually predict loading, unloading times and therefore make a more efficient schedule. I think there are big opportunities, but I'm not sure that it is being used now and especially not in the port
Interview 13	Yeah, so the port mainly is the ports role mainly is to facilitate in this sense. So if we look at port [...], what they mainly do is they do maintenance on jetties and they make sure the port is accessible and they also do some other like spinoffs [...] So they try to make the process of bringing goods into the Dutch mainland and feeding them to the hinterland more efficiently. So I think mainly their role is to ensure that that happens as good and as safe as possible.
Interview 16	you just need to put it In a safe spot somewhere on the building side and then you can do it. However, a ship needs to be in a harbor and preferably a bit of an accessible place where we can get to, so it requires a lot of planning with the company on when and where to do the maintenance for their vessels.
Interview 17	like if the ports will start to align their definitions, for example, how they communicate with vessels, if carbon regulations about emissions and reporting, it's much more strictly to have better data and information.
Interview 20	For me the key about port operation is the coordination of a lot of parties, so that the cargo exchange can happen in a safe and efficient way and sustainable way as much as possible.

Appendix E: Coding tree including Quotations, First-Order Categories, Second-Order Themes and Aggregate Dimensions

Quotation	First-Order Categories	Second-Order Themes	Aggregate Dimensions
a lot of the data is quite messy. It's not structured, so I do think it's important to analyse what the current data state is and see if it's actually already viable to be used by AI. Because in my opinion, AI can do a lot of things with unstructured and incorrect data. But I think it would also be very important to make sure that the data is already […] clean, so to say, or more structured and […], basically more standardized. So there's a lot of variation in the data and if we could bring that back already, so there's definitely some challenges before you can use AI properly I think.	Addressing data quality challenges for AI readiness	Legacy Infrastructure Assessment	Current Business Model Assessment and Technology Readiness
that shipping industry is kind of old-fashioned because you are creating, you are building a ship and the ship is at sea for 30 years […] it's not always built for modern data. For example, […] if you are talking about emissions, you want to know the fuel consumption, but for all the ships you are just looking in the fuel tank and say: oh, it's a halfway so we have so much metric tunnel fuel. […] That's also a challenge for the shipping industry.	Evaluating technological infrastructure constraints		
there is also no uniformity in the data transfer, the collection. So there are a lot of different companies, […] if you look at shipping, there are thousands and they all work in a different way, so it's very difficult to connect them together and also that the vessels will be there for such a long time.	Struggling with data fragmentation across platforms and legacy systems		

They (ERP vendors) are always lagging a bit when it comes to standing up with new ideas. [...] We are a bit hesitant when it comes to new developments from ERP vendor because they take time, they cost a lot of money and it's not always working. And then you know, it takes a lot of time to upgrade it. [...] but it's not always an improvement.	Facing slow innovation and integration challenges with legacy ERP systems		
it's also hard for someone that has been working for the company for 25 years to all of a sudden say hey, by the way, we're going to do this process that you are involved in. We're going to do it very differently. So we're going to digitalize this process and you're going to have to be doing this and this and this instead of this, this and this. That leads to quite a bit of resistance within the organization, [...] So you really have to be aware of what the impact on the on the on the people on the organization will be when you change a process	Encountering cultural resistance to digital transformation	Organizational Readiness Mapping	
In some projects that I'm involved in I see there's a lot of resistance when I sometimes they weren't informed even that I was doing a project. And then people are threatened by hey, why are you doing this with AI? Aren't I doing my job well enough?	Observing employee resistance to AI adoption		
Because if your management is not up to latest standards of technology, which is not common in our industry, then you have an issue.	Observing lack of leadership readiness for technology adoption		
the main challenge is to explain and educate people. We are in the industry, but also we are a company that has to explain and educate people. [...] we really had to catch up on that and get our act together that deals with transactional systems and the ERP implementation, but it also deals with data availability, data management data, more data-driven way of working.	Highlighting organizational challenge in technology implementation efforts		
everything that happened because of the value of the cargo that's being transported is tied to contracts that determine how the cost will be split across the parties. Who is responsible for what? at which moment of the journey?	Analyzing existing contract-based value distribution (current business model)	Market Position Analysis	
The value of Marine operator is the robustness of the service, so it's pricey. It's more expensive related to or in compared to competitors. But if you're if they're contracted, you know there's quite a certainty that the job will be done on time and	Competing on reliability and operational excellence		

in budget within budget. [...]And now it gives good confidence that things are going to executed correctly.			
In general, shipping companies own the vessels, make sure that there is some cargo on board and that they sail to A to B. [...] but a lot of stuff is outsourced to companies that specialized it. [...] also [...] to collect data. So a lot [...] is done together with other parties	Observing fragmented responsibilities across specialized maritime actors		
I think that especially in this area, transporting and logistics, they're always looking at where can I save money? Because the margins are very thin. I think because of that, they are open to any technology that can help them to save more money or to get a higher margin	Operating under thin profit margins in shipping		
Ships trading in Europe, if you carry your products on the same distance in Europe or the same distance outside Europe, it will have a different transport cost in these. If there are customers looking to use some marketing or so they could use it. And obviously we're open for that time to use a more environmentally type of fuel if they're willing to pay for it.	Observing to emission-related regulation affecting pricing structures	Sustainability Focus and Data Maturity	
A new business line? No, like, of course you have ETS, but the let's say the margins for selling the ETS, they are too low for us and also therefore not interesting to invest more in	Recognizing limited revenue potential from carbon markets		
So we need data to check it as well, because let's say for some vessels that were in the ocean, they were saving fuel, but on other vessels that are that were operating [...] they didn't save anything at all. But you need to use data or machine learning at some point as well to get that proof and evidence right in based on data if it works or not.	Requiring enough data and monitoring to properly assess the benefits of renewable sources of energy		
the shipping industry is mainly driven by legislation to become more sustainable.	Responding to regulatory sustainability drivers		
So that's I think the greatest challenge to then also basically get your management behind this, that they understand it, that also the people in the commercial department understand they have to develop this way and keep their eyes open in the technical department, in the accounting department. So it's really changing the organization towards, yeah, a new way of more data-driven and AI driven working.	Driving cross-departmental adoption of AI practices	Organizational AI Awareness and	Value Co-Creation: AI and Collaboration

You know, that also is development that is still ongoing and will be ongoing for quite some time still. So we really had to educate internally people and bring in new people to supporters in this journey.	Improving digital foundations requires workforce reskilling	Capabilities Development	
if you try to do too brutally too quickly, then people will feel threatened. That's why this is a risk. I see the risk that people will instead of collaborating, they will actively try to stall it. Or that's what we saw at some organizations. So I think you have to frame it. For some people it's a big change, so that's a risk.	Managing implementation pace to minimize resistance		
like an organizational challenge. [...] That's probably the larger challenge than the technological challenge behind it, which of course is also important [...] that's much more unknown and therefore the risk is maybe that people then take a wait and see approach. So bring it to me instead of looking out for it because it's there's still many question marks around it.	Overcoming uncertainty to proactively engage with AI transformation		
I must say that the AI digital development I just described on vessel and voyage performance optimization and also the decarbonisation efforts is currently still mostly driven by costs as well. And it's simply that both decarbonisation and digitalisation can give you fuel reductions. It's really a lot about fuel reduction and that's the business case. And the fact that with fuel reduction you save costs drives the whole thing or in a company like ours, because it's, it directly translates to your bottom line. [...], we know that fuel reduction also relates directly to CO2 reduction. So that element comes along as well.	Employing AI for cost efficiency that translates in emissions reduction as an effective approach	Strategic AI Technology Selection and Implementation	
So this value creation, like can also come from a theory sometimes, but it's how to find the balance, when to use the AI and when not to use the AI, but improve the for instance, the physical method	Evaluating the usage of AI against more well-known methods		
Microsoft Copilot is a little bit of use by office stuff. [...] but it's still not so easy to really find many use cases that people in our offices can immediately deploy. So I think [...] it's mostly on this vessel performance management that we'll use AI go for.	Focusing AI efforts on high-impact operational domains		
The simple answer would be is a for profit company. So the simple answer would be to increase efficiency, reduce costs. I would definitely say that those are the two main key drivers [...] we don't want to digitize	Pursuing AI adoption with clear business outcomes		

just because of digitization. The purpose would be to become a better positioned, profitable company in the future.			
having sort of a corporate data model is also. if your company has some maturity in how they collect data, right? Depending on how mature the company is, there's also the mindset. But in mature companies they develop a model that tries to describe the data reality in the in the company.	Creating standardized data architectures	Data Infrastructure Development	
we mainly want to increase the number of connected assets [...] because it's it gives us more opportunity to analyze data to help customers remotely. We're working on that as a priority	Expanding connected asset infrastructure for maintenance and monitoring		
But we have invested by having more data points on some of the ships to measure output on shafts, also measure consumption. That's a starting point.	Investing in data infrastructure to support efficiency gains		
smaller companies first need to get their data house in order, so they are usually not that structured actually. [...] I think in the smaller companies mainly use the main thing is planning, so I think planning is the most usually the most important parts.	Structuring data as a prerequisite for digital maturity		
We try to collaborate with companies like those, not with [engine equipment provider] in this sense, but with companies like [that], so to see. OK, how can we get the most out of their system? Because our system is only a small part of the puzzle. [...] but our product alone is worthless. It has to be coupled to other stuff. It has to be, so it's crucial to work with these companies.	Co-creating value through interoperability with strategic partners / vendors	Strategic Partnership Optimization and Collaborative Refinement	
if the ports will start to align their definitions, for example, how they communicate with vessels, carbon regulations about emissions and reporting, [...] much more strictly (would influence) to have better data and information.	Identifying port authorities as a major influence for industry standardization		
I think the relevance in having us help them with strategy is to get this for change management, I think some companies they really need some changes in the way they think about how their processes are doing right now and how they should be doing it with help of AI? I think that's where we can help them with.	Managing organizational change through strategic consultation		

And I think, companies now see that they are probably needed because they usually don't have the in-house knowledge to manage this new system.	Recognizing the value of technology partners for technical knowledge		
our big goal is to answer them within xx hours which is quite a stretch from what we do now. And we want we want them to always have insight into the status of their project or the service that we are doing.	Aiming for improved response times for customer service	Current Value Delivery Assessment and Enhancement	Value Co-delivery: AI-enhanced services
we're a service provider. [...] If we look at our line of business, the, we ship cargo from A to B, Nobody is nobody is actually requesting AI yet. As long as you deliver the cargo in a safe and sound condition to the port [...] So I don't think our clients are, when it comes to the service we provide, AI minded. Of course they have their own AI challenges or development or whatever, but that is not yet touching ours. Nor the business we do for them.	Delivering core value independent of AI visibility		
I think more in the of course in the in the entire logistics chain, there is value in tracking your loads, so tracking your cargo. It becomes more and more important, I think like we are very used to that. If you order a package, you can get its records and you can see the two-hour time window it will arrive. (accuracy)	Enhancing supply chain transparency through cargo tracking		
side you prepare your data and have that may be less prone to errors prepared. You still need to double check before it's sent out. And then you would also have more time to do the rest of the job and making sure that you can improve the quality there	Reducing error rates and improving service quality		
you have to have a much more automated and accurate communication with our customers. I think nowadays still a lot is going on by simply by e-mail, emailing a customer that whatever the ship is delayed or the ship is in time, but it has to wait in port before it can unload. You know, there's a lot of e-mail communication on this, whereas these kind of status updates, you know, should actually really be coming from an automated system.	Automating customer updates through integrated AI systems	Digital Customer Experience Integration	
I think especially the operators [...] they're taking quite a bit of time to inform all the customers of the whereabouts of the ships. If we can find a way how to process this data by AI for instance, [...] that would enable them to focus more on the work where that makes a difference.	Automating routine customer communication		

the way digitalization can impact our industry is that it may bring customers closer to the to the shipping company by linking them more up on providing data, on analysing data for them on the voyage that we did for them or the operation we did for them.	Enhancing customer proximity through data-enabled services		
So how can we improve basically the customer experience and the customer on-boarding on our digital tools and make it a bit more integrated into our offerings [...] making a good combination and helping them also make use an on-board on digital tools can really improve their customer experience	Implementing on-boarding to improve technology adoption		
for customers it can sometimes be a bit of a chaos of different applications I think that all their suppliers want them to install so that they can monitor their equipment. And I think that's what we're also currently facing that they'd rather have maybe an integrated platform or something that they can see everything on instead of separate solutions from all their suppliers.	Creating integrated customer digital experience platforms	Collaborative Service Integration	
we also see is that data sharing becomes more and more important so. To optimize your logistics chain or to optimize processes in the port area you need to work together with different parties. Actually you need to exchange data and of course,	Enabling cross-actor collaboration through data sharing		
there are some data collaboration efforts are being made to share data between like terminal owners and Authority to check how goods are flowing through the country.	Establishing cross-stakeholder data sharing		
I think if the shipping industry can standardize the way they communicate, then we can start automating it. But if you have different protocols for every port you visit, it is a nightmare.	Prescribing cross-industry standardization of communication protocols for automation		
For me, it's time [...] to train it in the right way, to make sure that computation doesn't take as long as it should be, because the order of time in like this [...] should be maybe two minutes or less for.	Employing AI in time-constrained decision making	Operational Intelligence Optimization and Reevaluation	
So it's basically a very big puzzle with small pieces in there. [...] and so for us it's more and more on sort of seeing how can we use data, how can we use AI to provide the operator with actual feedback that they can sail more safely, more sustainably, without having directly get rid of the human there.	Enhancing human decisions with AI-generated feedback		

There's one area where I believe that is furthest advanced, which is the area of what you could say vessel performance management. Which ranges from, you know, from voyage optimization, how to sail your ship from A to B in the most efficient way, the most efficient route, but also speed regulation. So what's then the optimal speed to make it in the required time to your destination? Don't come there too early by speeding up, you mean enormously and then have to wait. That's an issue in our industry. Same with how to reduce ballast legs,	Optimizing performance of vessel operations using AI and machine learning		
You see it in general that there's more data points and people are trying to gather more data and even be with this data they will try to change from preventive maintenance where at a certain set interval you change, for instance, a filter.	Transitioning to predictive maintenance models		
a voyage optimization system and that system is charging [...] like I think 1 metric ton of fuel [...] So if you can save one metric ton of fuel, you have recovered your investment on that voyage	Achieving rapid ROI through fuel optimization	Efficiency-Based Profit Optimization	Value Co-capture: AI-enabled revenue models
(Ports) are incentivizing them (vessels) to come with better utilization of the vessel. So it doesn't mean bringing more cargo each time, so it that this visit is more sustainable for from the perspective of the vessel. So instead of for example carrying 1000 TEUs and then crossing the ocean or crossing long distance with this amount of cargo (ports) are giving incentives for them to come with, let's say 2000 TEUs and this means that this trip had a better efficiency in terms of how much cargo it transported in terms of fuel consumption.	Creating efficiency-based pricing models		
I think that's a universal thing within shipping, like the margins are really low, there's always a high risk involved and the margins are quite low. So also investments into sustainability is second choice. Let's say the first part is writing black numbers. [...] if you sail more efficient and therefore uses less fuel, which is more sustainable and directly impact your operational costs. So that is, in my opinion, the incentive to go green	Prioritizing profitability over sustainability in investments		
They are competing very hard with each other. I know, and the margins are very thin. So when they can use AI to have a smarter scheduling, for instance	Seeking cost-saving technologies due to competition		

we actually have built a specific dashboard to show them, OK, well what are the exact numbers of our emissions and what are the exact consequences based on all the different rates. So they have rates for worldwide, they have rates for specifically for Europe due to all the regulations there. And we indeed [...] helped them to make that more insightful	Monitoring emissions for regulatory compliance	Performance and Compliance Value Integration	
(when discussing response to market situation) make sure that we remain profitable. That is like an important part. [...] but also [...]we need to do something on being sustainable, right? We cannot do what we used to do like 15 years ago. [...] people want to know how much CO2 or we're emitting.	Responding to sustainability expectations with emission tracking		
we help them with ESG management. So environmental, social and governance. So, for sustainability data and the data collection, but also using AI features on top of that for missing data or to do predictions.	Using AI to enhance ESG compliance		
and then you get a statement of compliance. And it's also I think a trade enabler that if you can prove with statistics and with those certifications that [...] safety is good [...] on the vessels, then it will give you an advantage.	Using safety compliance recognition as a competitive advantage		
On the commercial side, many ships are being booked through brokers. That's is also an important element in the ecosystem right now. But will that stay that way or will there be one day the rise of a larger platform, an automated platform where you can bring supply and demand together? Not happening yet, but maybe that's a question mark for the future.	Anticipating platformization of maritime freight booking	Data Monetization Strategies	
And maybe the, our industry is still at the, call it the initial steps of pricing in the CO2 emission because our clients want to know, but they don't act on it yet. So they want to measure. And we have to fill in all kind of forms like, OK, we have emitted so much emission to carry your parcel from A to B. But these companies are also [...] collecting the information from our competitors and [...] they're not making business decisions yet on that. [...] we do all kind of initiatives to lower our emission, but that is not a crucial factor yet where charters	Considering CO2 transparency to influence commercial decisions		

are deciding on. For them, it's either price or delivery windows that that is more important at the moment. But we hope that the future will bring us one step further.			
at least the bigger companies are actually adding business models to their usual business by creating platforms with their data, which is very useful for other parties and arrival times estimations and stuff like that, [...] They noticed that you could extend your business using data you actually already have, but then creates a paid platform out of it. And I think other and new companies arise that they don't do anything operational themselves, but they just combine data from different parts in the logistics chain and create an advantage if you become part of their platform, actually.	Creating data-driven business extensions for providing visibility of the operating activities		
What can be new is when you go to a bit like this perspective like almost a marketplace of data in which you start adding the non-mandatory services in which players across the chain can exchange information using this neutral platform to improve their operations and then they can charge for that as they find it convenient to do	Developing data marketplace capabilities		
But then for the customer, it also has an incentive to help us together to do together a more optimized service by simply coming in time. So we reduce the fuel emission, the fuel consumption and the emission and the customer has a better service by not having to pay the demurrage and the trick is, of course, how are we going to redistribute the benefits that are related to a more, yeah, just in time service?	Incentivizing joint optimization requires sharing and bringing visibility of logistics benefits	Collaborative Value Refinement	
recently we changed our policy to instead of incentivizing just to bring more to have more visits, we are now incentivizing investors to have bigger port calls. [...] we are incentivizing them to come with better utilization of the vessel	Redesigning incentive structures for efficiency and sustainability		
if a customer wants to agree to get connected for example, we can take the cost and then OEM also supports us again in taking these cost.	Sharing implementation costs with partners		
But our main goal with our company is not just do consultancy based on ours, but to deliver more project and more managed services. So building a solution in a project and afterwards managing that solution for a fee each month. So that it's more recurring	Transitioning to recurring revenue models for IT services		

if you sail empty, well, that's really the worst of the worst in a way, it's cost twice, costly, but also for decarbonization, yeah, you're just transporting air, so no good.	Avoiding ballast trips to cut emissions and costs	Economic Sustainability Integration	Sustainability benefits realization
there is an organization and if you get the gold medal from them. [...] You will get a let's say discount when you call the CargoGate. It's a green award [...] But that also applies for that we can get if we then go to NaviTrus with this green award certificate, they will say, OK, you can get half a percent, not half percent like 0.05% discount on your interest, things like that.	Earning sustainability incentives through operation improvements		
by saving fuel, let's say for some vessels, we save about 10 to 15% of fuel. So we save the actual fuel being bought by the operators or by the vessel owner. But it also saves a lot for the environment	Reducing fuel consumption through smarter control		
Yeah, I think it's a lot about finding the immediate business case. [...] we have to write black numbers as well. So you cannot invest yourself to bankruptcy that that doesn't make any sense. So we need to keep finding the business cases and that can sometimes be financial and sometimes be more on the environmental part or the social part.	Requiring solid business cases for sustainability investment		
I feel like the paradox of AI, [...] you want to use it for off-design conditions. But then also you want to know, is it really trustworthy in these off-design conditions? Is it correct what it predicts or calculates or is there some sort of reproducibility, a predictability to what the result is?	Addressing AI trustworthiness in critical applications	Social Value Creation	
AI can play a role in, in health and safety by simply avoiding or being able to avoid dangerous situations, that human beings would not quickly indicate as a dangerous situation. And by having all these data available in the world of marine injuries, accidents, incidents, I think you can really through AI improve also our performance. [...] if you look into that for health and safety, I think that's for instance, in our company we would like immediately do that. If there will be an AI driven development that would improve our safety score, then I think quickly we will [...] try to adopt it. Simply because any human injury, any human life that can be saved through it is worth a lot of money, So the business case is quickly there.	Improving safety outcomes with AI-based risk detection		

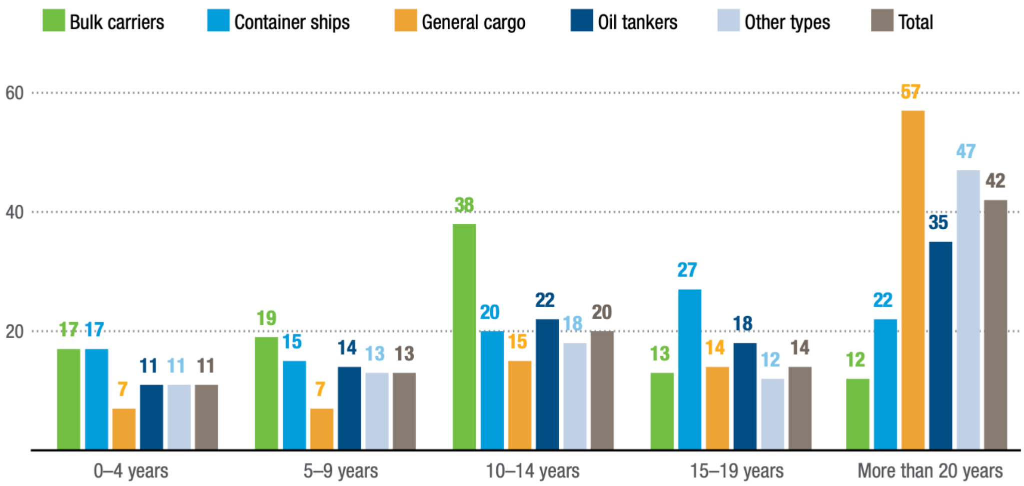
you try to factor in other aspects besides keeping the feet dry and making sure that ships can move as fast and as smooth as possible of the water rate. So you also want to think a bit ahead about is the space that we live in. Is it still liveable?	Integrating a long-term view for sustainability		
There's also clients that actually now are performing due diligence on us on human rights, for example, they really ask us, OK, how are human rights within your organization's, how are they settled and also at our suppliers and they actually want proof on it.	Responding to client social sustainability demands		
Reducing CO2 that is, [...] the biggest challenge we have. And we're doing all kind of efforts and all kind of ideas we are exploring to see how to reduce CO2 [...]. If you look at the CSRD Corporate Reporting Sustainability directive, [...] it's definitely more than then only emitting CO2. It's like how you work with your colleagues, how as a company we take care of the colleagues. [...]What is the biggest focus? It is reducing CO2.	Balancing environmental and social goals in sustainability strategy	Environmental Impact Optimization	
we need to be conscious that behind these AI methods there's a lot of energy consumption [...] There's a lot of work, so if you go back to the chain of how you get access to, for example LLM models. They are not super-efficient in terms of resources utilization.	Managing AI sustainability trade-offs		
also if sustainability is maybe not the initial driver, but of course if ships are not waiting with their engines running in at before the port because there is delays and they cannot get to the to the gate to unload their cargo, it's of course also win for in terms of sustainability. So I think in better predicting and better and optimising those plannings, there's. already a very lot to gain when you look at sustainability as well and especially I think emissions in the port, because of ships waiting there with their engines running.	Reducing idle emissions with AI-enhanced port scheduling		
The other challenge was that it's actually [...] quite difficult to really measure the impact [...] quite well. You need a lot of data points to be able to eliminate any impact from wind and swell and any other external factors to really find out what's the benefits [...] was and something we have heard also from other companies. You don't typically read that in the headlines of the newspapers, but I believe it's still very difficult to measure the impact.	Struggling to measure the impact of technology-based sustainable solutions due to poor data availability		

Appendix F: Average age of world fleet, percentage number of vessels, 2024

As indicate in the review of maritime transport 2024, figure II.5 (United Nations Conference on Trade and Development, 2024)

Figure II. 5

Average age of world fleet, percentage number of vessels, 2024



Source: UNCTAD calculations, based on data provided by Clarksons Research Services.
Note: Propelled seagoing vessels of 100 gross tons and above, as of 1 January 2024.

Source: United Nations Conference on Trade and Development. (2024). Review of maritime transport 2024: Navigating maritime chokepoints (UNCTAD/RMT/2024). United Nations Publications, *https://unctad.org/system/files/official-document/rmt2024_en.pdf*

Appendix G: Explicit quotations about the traditional or conservative culture of maritime industry

Interview	Quotation
Interview 05	That people in the organization support these initiatives, you know? What I was saying it's an old a bit traditional. There's a lot of old people working here, you know. So before they say: Oh yes, you know this has potential or it's useful. It takes some time. You know, a lot of people need convincing.
Interview 08	I think the maritime industry in general can be considered a little bit more traditional than, for instance, the car industry. I think there are many reasons for that, but as an example also, for instance, legislation. Like legislation on car is more modernized, maybe more sustainable already than the maritime industry, so in that sense. We don't have to follow as strict legislation yet in the maritime industry, so the pressure to innovate and to come up with, for instance, sustainable goals is, I believe a little less there
Interview 09	So it's quite conventional. I think a lot of companies and a lot of innovations are happening, but still the ports and maritime sector is lacking a bit behind and especially in the Netherlands, actually. If you compare to China and Japan and Singapore. We're not so much in leads when it comes to very smart innovation.
Interview 12	Yeah, far from mature. I think as I mentioned before, the technology acceptance, it's just a conservative, quite conservative industry with elderly people
Interview 13	So ports and shipping is quite conservative, so that's the main thing that I have (experienced) as well.
Interview 14	And all other type of challenge is that shipping industry is kind of old fashioned because you are creating, you are building a ship and the ship is at sea for 30 years? [...] it's not always built for modern data
Interview 16	I don't know if you've heard this, but I think maritime industries quite conservative is also still quite physical. Offline as well and I think we're more and more looking to how can we also enhance our service to our customers by offering them also digital tooling without making it impersonal
Interview 17	also the shipping industry is a bit old fashioned. So some of the vendors, they don't have technology themselves yet. So they're still building their own APIs or something like that too.

Interview 18	people are conservative and that's shipping is a bit of a conservative world. Although I think it's slowly starting to move and move forward
Interview 20	the industry is widely recognized as one of the most traditional ones, so we see that when we try to digitalize operations with our customers we face a lot of resistance to shift from the ways the way you manage your operations for years and years
Interview 21	if you see the shipping industry that's a little bit old fashioned in in a way and the last two years it opens more opportunities on the ships themselves. So I think you can speak of a kind of revolution there in introducing more and more data
Interview 22	And then specifically maritime is very conservative kind of we're doing it according to the old ways kind of business. So it's within all the different sectors. It's one of the most conservative ones, I think. So getting that data-driven and especially getting all stakeholders data-driven is a challenge.

Appendix H: Interviews composition across organizational and individual dimensions

# Interview	Role	Company	Organization Size	Years of experience	Seniority
01	Account Executive	Kappa	51-500	6-12 years	Specialist
02	Co-founder / Chief Financial Officer	Zeta	2-50	6-12 years	C-level executive
03	Data Consultant	Lambda	1000-5000	0-5 years	Specialist
04	Sustainable Value Chain Lead	Omega	51-500	6-12 years	Department Head
05	Development Lead	Omicron	1000-5000	6-12 years	Specialist
06	Commercial Director	Beta	2-50	21+ years	C-level executive
07	CSRD Manager	Lambda	1000-5000	13-20 years	Senior Management
08	Chief Financial Officer	Delta	51-500	6-12 years	C-level executive
09	Innovation Manager	Theta	2-50	6-12 years	Senior Management
10	Chief Financial Officer	Alpha	51-500	21+ years	C-level executive
11	Head of Alliances	Lambda	1000-5000	21+ years	Senior Management
12	Business Optimisation Coordinator	Alpha	51-500	0-5 years	Department Head
13	Modelling Specialist	lota	+5000	0-5 years	Specialist
14	Data Consultant	Lambda	1000-5000	0-5 years	Specialist
15	Tech Lead	Sigma	+5000	6-12 years	Department Head

16	Data & Tech Manager	Epsilon	51-500	6-12 years	Department Head
17	Chief Technology Officer	Alpha	51-500	13-20 years	C-level executive
18	Services Manager	Beta	2-50	21+ years	C-level executive
19	Data Scientist	Lambda	1000-5000	6-12 years	Specialist
20	Data & Tech Lead	Gamma	1000-5000	6-12 years	Specialist
21	Unit Manager	Lambda	1000-5000	13-20 years	Department Head
22	Programme manager	Gamma	1000-5000	13-20 years	Department Head