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Advancing sustainability through digital servitization: An exploratory study in the maritime shipping industry

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ABSTRACT

Global businesses are transforming towards capturing more value from services, a business model transition called servitization. Digital servitization can help create and maintain a competitive advantage, as well as offering opportunities to tackle major challenges related to environmental pressures and rapidly changing market conditions. This study aims to bridge the gap between the theory of digital servitization and its implementation in the maritime shipping sector. This paper presents a multi-case study that explores the status, perceived challenges, and enablers for the adoption of digital servitization. Empirical data were collected from interviews with 13 companies and analyzed using the PESTEL and DPSIR frameworks. The results are presented across three categories based on the PESTEL framework: organizational context, global priorities, and sustainability. This study contributes to theory by providing empirical insights from the status of digital servitization in the maritime shipping industry. Also, it identifies challenges and needs that can support the transition towards digital servitization and the development of more sustainable solutions. Future research avenues are suggested to advance digital servitization in other industrial sectors.

1. Introduction

The maritime sector is a major pillar in global logistics, transportation, and commerce, being responsible for the carriage of around 90% of world trade (Casella et al., 2019). This sector also experiences growing pressures to become more sustainable and stay competitive. External stressors and global drivers, such as accelerating globalization, increase the pressure for improved efficiency in maritime shipping where the search for more sustainable modes of operation stimulates new business models that support value capture through the adoption of digital technologies (Tull, 2014; Gavalas et al., 2022).

The last two decades have seen the maritime industry continuously transform and strive to improve its adoption of technology and new business models (Fruth and Teuteberg, 2017). These changes are driven by amplified competition, increased customer expectations, the wish to reduce costs (Tijan et al., 2021), the need for compliance with standards and regulations (Pinto et al., 2015) and the required adaption with interfacing systems (Ghaderi, 2019). Recent studies have called for a servitization approach to achieve goals such as efficiency and improved sustainability (Zhao et al., 2022), but research on new business models in the maritime industry remains scarce (Del Giudice et al., 2022). However, in this sector, the large capital equipment, intense maintenance requirements, retrofitting, upgrading and service logistics, represent a significant part of the overall operating costs (Eruguz et al., 2017). Thus, digital servitization could be a suitable approach to improve value propositions, as it identifies sustainability benefits when intentionally designed.

Digital servitization can support companies to retain competitiveness and increase value-capture by delivering more value than with tangible products and add-on services alone (Paschou et al., 2020). Most companies are pursuing sustainability objectives that can be addressed through servitization (Yang et al., 2017; Aiello et al., 2020), through dematerialization, extended lifecycles, additional revenues, customer retention, and engagement with new ones in tighter relationships (Gebauer et al., 2005; Yang et al., 2017).

Digital servitization is a growing research field, but the

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documentation of sustainability implications in the maritime sector is still at an early stage. Some available research includes required digital capabilities in a servitized maritime shipping sector (Pagoropoulos et al., 2017) and supporting digital technologies, such as blockchain (Zhao et al., 2022), autonomous solutions (Makkonen et al., 2022), and service-design processes for smart Product-Service Systems (PSS) (Solem et al., 2022). Maritime shipping is known to be a complex, multi-stakeholder industrial sector which could benefit from digital servitization to better deliver value, create competitive advantage and promote more sustainable behavior. However, there is still a gap around the enablers and constraints that influence such business models in this specific context.

Complex industrial sectors can benefit from simple and effective analytical frameworks that bring clarity to conceptual connections in industrial cases. For instance, the DPSIR (Driver-Pressure-State-Impact-Response) framework (Tsangas et al., 2019) has been suggested as a tool to study the maritime context (Atkins et al., 2011). The DPSIR framework concretizes environmental problems and solutions into variables that stress the cause-and-effect relationships between human activities which exert pressures on the environment and clarify the response to these conditions (Zhang and Xue, 2013). Further, the PESTEL (political, economic, social, technological, environmental, and legal) framework is a tool designed to identify factors that may affect business strategies and to assess how different environmental factors may influence business performance (Johnson et al., 2008).

This study is guided by the following research question: What are the influencing factors for digital servitization to deliver sustainable solutions in the maritime sector? To answer this question, we followed a multiple case study approach to identify the internal and external factors, through the combined use of PESTEL and DPSIR, that influence companies in the maritime shipping sector in Northern Europe.

The next section provides the theoretical background with the concept of digital servitization and contextualizes it in the maritime shipping sector. Section 3 describes the methodology followed in this study. Section 4 presents the case studies' results. The theoretical and empirical implications are then discussed in Section 5. Finally, Section 6 presents the conclusions of this study.

2. Background

2.1. Digital servitization

Servitization and digitalization are two disruptive trends reshaping the industrial landscape (Tronvoll et al., 2020). Servitization is defined as "*the transformational process of shifting from a product-centric business model and logic to a service-centric approach*" (Kowalkowski et al., 2017); digitalization has many available definitions but is defined in this study as "*the use of digital technologies to change a business model and provide new revenue and value-producing opportunities*" (Bloomberg, 2018). Digitalization is considered an effective enabler of servitization, as it is indispensable to characterize offerings, propose broader and articulated service offerings (Pezzotta et al., 2022). Also, digitalization provides increased lifecycle data, which can generate value through consciously designed data flows and analysis (Cenamor et al., 2017), allowing companies to become more efficient, flexible, and practical by ensuring precise customer needs are covered (Xin and Ojanen, 2017). Often, digitalization and servitization are researched in isolation (Paschou et al., 2020), leading to a gap between the rapid speed of digital transformation and the pace of the adaptation processes (Luz Martín-Peña et al., 2018).

Research from the last decades has challenged the previously prevalent product-centered business models, claiming they do not guarantee success (Kindström, 2010), motivating firms to embrace digital servitization. Digital servitization is defined as the combination of new technologies, connectivity and data analysis delivered through services can create new and more sustainable value propositions by building on integrated product-service-software systems (Kohtamäki et al., 2019). In this transition, the term PSS has played a central role in understanding how product/service bundles can cover needs and deliver value through added services and activities that focus on creating results-based offerings (Tukker, 2004; Baines et al., 2007). Digital servitization can also deliver sustainability advantages (Paiola et al., 2021); for example, enabling the transition toward a circular economy through dematerialization and the more intensive usage of physical assets (Hojnik, 2018; Hallstedt et al., 2020). Service strategies in the form of maintenance, monitoring, reuse, resale and remanufacturing create new business opportunities from a value-capturing perspective (Spring and Araujo, 2017).

Advancing sustainability through digital servitization requires the involvement of regulating bodies, governments, transport ministries and port authorities, as most companies react to emerging regulations (Fasoulis and Kurt, 2019a,b; Jović et al., 2020). Further, digital servitization can enable synergies between environmental and economic sustainability (Reim et al., 2015; Bocken et al., 2016) as they can increase stakeholders' loyalty, maximize resource usage, enable transparent communication loops, provide cost competitiveness, commoditization and foster collaboration (Rabetino et al., 2018). However, recent research has also identified that transitioning companies might face challenges in generating revenues from services in their portfolios, limiting the shift of paradigms (Pezzotta et al., 2022). This brings light to the need for managers to evaluate the positive and negative economic implications of digital servitization (Rakic et al., 2022) to avoid the so-called "servitization paradox" where firms do not obtain the expected results after adopting digital servitization (Gebauer et al., 2005).

2.2. Digital servitization in the maritime sector

The maritime industry is undergoing continuous technological and organizational development in response to the increasing demands for productivity, efficiency, and sustainability (Heilig et al., 2017). Digital servitization is of relevance to the maritime sector as it provides benefits to long-life tangible assets, that can benefit from lifecycle management (Norden et al., 2013). The maritime sector naturally combines tangible assets with added services which can extend lifecycles, where the capital-intensity of the industry presents opportunities and suggests positive candidacy for digital servitization (Pagoropoulos et al., 2017).

The continuous increase of digitalization is one of the primary factors driving digital servitization in the maritime sector. Furthermore, this sector has been exposed to an increasing list of relevant technologies such as remote monitoring, cloud, cyber security, big data, real-time connectivity, and platforms (Tóth et al., 2022). Tijan et al. (2021) identified that some new companies appear in the market with disruptive business models, but the trend is that most companies retain their traditional business model, risking competitiveness. Recent research has documented the use of alternative business models, in applications such as performance-based contracts as basis for operations (Pareliussen et al., 2022). Such initiatives mainly find economic benefits, as servitization is expected to decrease costs and support the increase of revenues in shipping activities (Pagoropoulos et al., 2017).

Another incentive for the adoption of digital servitization in the maritime sector, refers to the increasing environmental concerns. For example, Sulphur regulations and the push for emission-free operations, have been addressed through different contract arrangements (i.e. shared costs models and service-based contracts) that promote win-win situations (Olaniyi and Gerlitz, 2019) like shared savings between stakeholders. However, this business model also poses challenges for the incumbent firms, particularly in the maritime sector, as it is considered to bring tensions and paradoxes and contradictions (Sandvik et al., 2022). For instance, it is known that innovation in the maritime shipping industry is driven by the push of connectivity, digitalization, and traceability, among others (Lloyd's Register QinetiQ, 2015; Alcayaga et al., 2019). However, although digital technologies can transform entire supply chains, the maritime sector has many limitations.

The adoption of digital servitization in the maritime sector is associated with some challenges. Innovations such as digital servitization require large networking webs, which in this sector are challenged by a lack of general managerial and technological capabilities (Simmons and McLean, 2020). From a technological perspective, digitalization, as a key element of digital servitization, requires dealing with large amounts of data (Aiello et al., 2020), but some companies in the maritime sector encounter a lack of availability and skilled management of the data (Will and Greistch, 2014; Claramunt et al., 2017), which can limit digital business model innovation. The knowledge and experience of seafarers are scarcely captured in information networks that inform rule-making processes, limiting enriched learning and digitally capturing workers' experience (Alderton and Winchester, 2002). Further, the lack of 24/7 broadband connectivity, is identified as an urgent problem to address for digitized shipping to leverage the efficiency of a globally networked business model (Aiello et al., 2020).

On the note of managerial capabilities, the maritime shipping sector can be considered a complex arrangement of organizations that compete but can also cooperate to increase innovation and productivity (Kitada and Bhirugnath-Bhookhun, 2019). Digital servitization transformations involve processes that are best supported when including multiple stakeholders, as the involvement of several actors enables the identification of sustainable practices and facilitates embedding them into corporate strategies (Del Giudice et al., 2022). However, despite multiple existing categorizations, some of the main stakeholders in the maritime sector include shipping companies, shipbuilding companies, equipment manufacturers, classification societies and government, international organization (Kim et al., 2020).

Furthermore, the rapid evolution of technology and managerial strategies brings along other sector-specific challenges, which in this case include culturally mixed crews, lack of consultation and negotiation procedures, varied tours of duty regarding nationality and rank and fragile organization of trade unions (Alderton and Winchester, 2002). Overcoming such barriers through managerial and technological development (Simmons and McLean, 2020) can benefit from the servitization of data and technological knowledge to support new and sustainable ways of capturing value through knowledge-based decision-making, i.e. in "smart shipyards" (Koilo, 2021).

2.3. Digital servitization for a more sustainable maritime sector

Sustainable business models have been documented in the maritime sector, such as servitization, as means to comply with new environmental regulations (Schiavone et al., 2022). The connection between the maritime industry and sustainability issues has attracted research efforts on technological and innovative solutions to reconcile economic growth and environmental protection (Del Giudice et al., 2022). To date, few empirical studies have analyzed advancing sustainability through digital servitization (Poulakidas, 2014; Wahab et al., 2018). One such study connects the after-sale service provision of ships to the concept of PSS (Pagoropoulos et al., 2014), presenting some sustainability-enabling synergies through service-based business models.

Although there are few documented examples of sustainability-driven innovations that focus on servitization, approaches such as Corporate Social Responsibility (CSR) are documented as strategies for regulatory compliance (Stevens et al., 2015; Fasoulis and Kurt, 2019a, b). For instance, Olaniyi et al. (2018) identify regulations as an incentive to integrate performance-based business models, arguing that shared ownership and distributed costs could promote the implementation of scrubber technologies. In this example, service-based strategies do not claim automatic reduction of environmental impact, but it exemplifies how regulation-driven initiatives can benefit from digital servitization.

Moreover, companies in the maritime sector are continuously evaluating new ways to reduce emissions and improve sustainability through trade-offs between economic and operational objectives (Mansouri et al., 2015). Some documented cases are found in Danish and Greek feasibility studies for PSS implementation, which analyze how business strategies can enable shared costs and environmental benefits from offering performance as the main source of value (Pagoropoulos et al. 2014, 2017; Rivas-Hermann et al., 2015).

In summary, studies have exemplified that new business models, such as servitization, are required for the maritime shipping sector to achieving resource efficiency, reliability, safety, and decision support (Kitada and Bhirugnath-Bhookhun, 2019). A recent literature review (Makkonen and Repka, 2016) reports a lack of clear consensus on the impacts of environmental regulations on maritime transport, as the economic and innovative reasoning behind them can be conflicting. On the one hand, stricter environmental regulations could have a positive effect on a company's strategies to achieve a competitive advantage, leading to more innovation strategies (Sampson and Ellis, 2015). On the other hand, there is still sensitivity around economic investments assume to be required to address environmental issues, in maritime operations, but this does not necessarily align with sustainability initiatives (Lister et al., 2015). Therefore, studying digital servitization as an enabler of sustainability in the maritime sector is an avenue for timely research.

3. Methodology

This research study followed qualitative research methods (Creswell and Creswell, 2017). The research problem was defined through collaborative research projects with experts from the maritime shipping sector. Multiple case studies are a suitable method to investigate research topics still in their infancy, such as the relationship between digitalization, servitization and sustainability in the context of the maritime industry (Wohlleber et al., 2022). In addition, there is a lack of industrial cases which address these three perspectives in the context of the maritime sector. Considering the objectives of the study, this cross-sectional research design (Bell et al., 2022) provided a broader perspective to capture the diversity of stakeholders involved rather than in-depth analysis of individual companies.

This section describes the research process followed in this study, as summarized in Fig. 1.

To better understand the industrial challenge and define the study objectives, the researchers performed a "backyard" study (Glesne, 2016) through an integrative and exploratory literature review, company visits, and project workshops within a consortium of researchers and industry experts from the Baltic Sea Region. These backyard activities informed the design of the interviews performed in the case studies.

The literature review focused on servitization in the shipping industry primarily, with keywords such as "shipping", "maritime", "vessel", "business model", "servitization", and secondary keywords related to "digitalization" and "sustainability". The literature search was complemented with snowballing (Dragan and Isaic-Maniu, 2013) and recommendations from researchers in the maritime sector. While the maritime sector has a long history, most of the literature found for this exploratory review dates from 2006 onward.

3.1. Case definition

In preparation for the case studies, Patton (1990) recommends using "purposeful samplings" for multiple case studies. This way the researcher can obtain a sufficient information from diverse sources which address the research inquiry.

The company selection and data collection in the case study followed the process suggested by (Miles and Huberman, 1994):

- Setting: The research study included companies located in Northern Europe, most of them in Sweden, Finland, Denmark, and Germany,

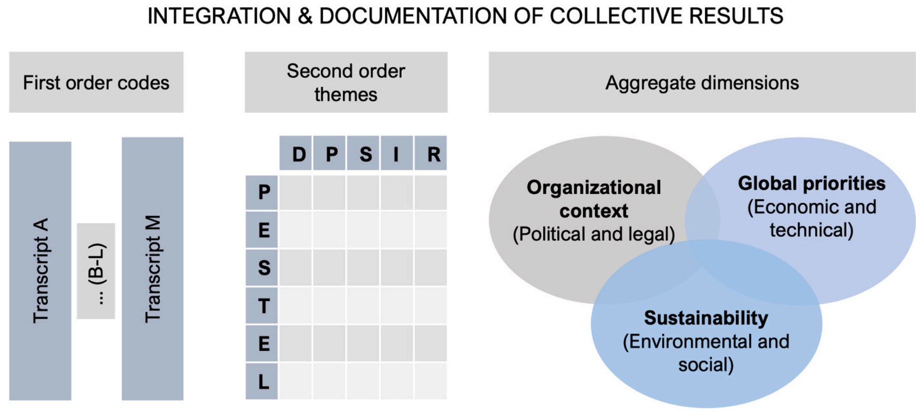

Fig. 1. Research process.

setting a certain standard on the technological, economical, and innovation-related decisions they undertake.

- Actors: All the companies operate within the maritime sector, with interest in digitalization to achieve sustainability, and express interest to engage in new business models.
- Events and process: The actors were interviewed about their experience while working in the maritime sector.

The case companies selected represent the stakeholder groups shown in Fig. 2 – service providers, shipping companies, equipment manufacturers and shipbuilding companies. In this adapted version from (Kim et al., 2020), the elements in blue represent the stakeholders who were interviewed, with the addition of service providers. The service providers package their value proposition in the form of a service which supports the client (Mathieu, 2001). In this selection, governmental and international organizations, and classification societies were not selected as candidates for the interview process do not directly provide commercial services, as the aim of this study is to analyze companies' perception.

As suggested by (Yin, 2018), a minimum number of cases is necessary to identify patterns. Initially, seven cases were conducted with companies A-G, considered a sufficient number of cases for the development stage (Creswell and Creswell, 2017) (pg. 189 Designing research), as detailed in the first half of Table 1. Companies H-M were added for the validation stage, detailed in the second half of Table 1. The addition of these six case companies allowed the researchers to reach saturation (Creswell and Creswell, 2017).

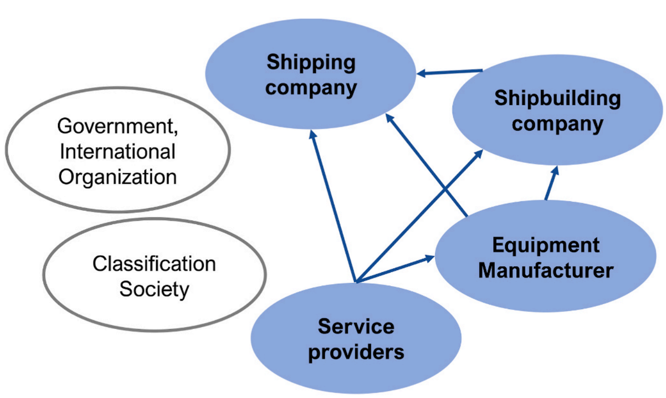

Fig. 2. Mapping of stakeholders included in the case studies (highlighted in blue) and their connections through service provision. Adapted from (Kim et al., 2020) with the addition of service providers. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.2. Case selection and definition

Each case company A to M was treated iteratively with a multi-stage process:

- Pre-study: Each case started with company visits, project meetings, and surveying companies' websites.
- Data collection: An interview protocol was used in the 14 semi-structured interviews to guide the discussions while allowing the participants to further expand on their area of expertise. The interviews were conducted digitally or face-to-face, lasted between 40 and 60 min, and were performed by at least two researchers. The interviews were recorded and transcribed.
- Cross-case analysis: The thematic analysis was performed following the step-by-step guide to create a data structure through a qualitative approach to produce insightful observations systematically across all cases (Gioia et al., 2013).

After analyzing the transcripts and creating first-order codes, second-order themes were developed for the cross-case analysis. This was done by analyzing the first-order codes through a combination of PESTEL (political, economic, social, technological, environmental and legal) and DPSIR (Driver-Pressure-State-Impact-Response) to capture the multidimensional nature of the system investigated (Tsangas et al., 2019). The PESTEL is an analysis tool focusing on external factors impacting an organization, enabling the identification of business opportunities. DPSIR is a stress-response model (OECD, 1993; EEA, 1995) used to guide reporting and assist policymakers in identifying cause-effect relationships between humans and the environment. The results are presented into three aggregate dimensions based on the PESTEL framework (section 4) and further discussed using the DPSIR framework (section 5). Finally, a summary of key findings from the cross-case analysis is presented to conclude (section 6).

The authors reduced bias by collaboratively performing the literature review, interviews, coding, and thoroughly documenting the results (see Appendix).

4. Results

This section presents the case study results based on the 14 interviews performed. The interview data analysis followed the PESTEL and DPSIR frameworks to code and structure the results (see coding table in Appendix). The core findings were organized using aggregate dimensions of the PESTEL framework (Fig. 3) to vertically assess several external factors that influence the adoption of digital servitization in the maritime shipping sector. The **organizational context** reflects the political and legal aspects of the PESTEL framework. Then **sustainability** includes social and environmental aspects. Last, technical and economic

Table 1
Companies selected for the case studies.

	Company	Informants role	Company description	No. of Employees	Type of actor
Development stage	A	CEO	Solution provider of repairs and installations to shipyards.	28	Service provider (Marine repair)
	B	Head of Strategy and Innovation	Ship design and provider of solutions for utilization of data	800	Service provider (Marine design)
	C	CEO	Naval architecture and engineering consulting to ship owners and shipyards.	50	Service provider (Marine design)
	D	COO	Consulting company providing software and automation systems.	120	Service provider
	E	UX & Service Design PLM Implementation Lead	Shipbuilding company, specializing in the building of cruise ships, car-passenger ferries, and special vessels.	2000	Shipbuilding company
	F	Naval Architect	Marine engineering company dedicated to designing, retrofitting and implementing propulsion systems and project handling.	90	Service provider (Marine design)
	G	Director of Digital Architecture	Marine shipping and energy transportation company.	2500	Shipping company
Validation through additional cases	H	Connected Service Manager	Solution and expertise provider that supports ship owners and operators through innovative service solutions.	17,000	Service provider
	I	Head of Product Management	Manufacturer and maintenance-provider of turbochargers for diesel and gas marine propulsion engines.	2000	Equipment manufacturer
	J	Chief Information & Technology Officer	Shipowners and operator of a fleet serving the oil, gas and dry cargo markets.	50	Shipping company
	K	Project and Product Leader of Digital Partnerships	Global container shipping company and solution provider	150,000	Shipping company
	L	General Manager of Global Sales	Maritime service provider of lifecycle power solutions.	17,500	Equipment manufacturer and service provider
	M	Chief Business Officer	Tech company supplying vessel monitoring, fleet tracking and voyage optimization applications.	25	Equipment supply and service provider

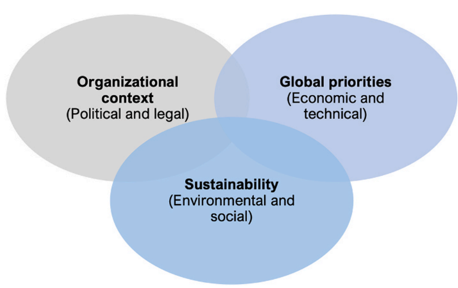

Fig. 3. Aggregate dimensions to structure the results based on the PESTEL framework.

aspects correspond to companies' internal motivations and **global priorities**. Additionally, the DPSIR framework was used to analyze how the companies interviewed respond internally to digitalization and servitization.

4.1. Organizational context

This subsection summarizes and exemplifies the findings related to political and legal aspects observed. For instance, the increasing government initiatives appear to drive digitalization and new business models that support sustainability, such as digital servitization. For instance, Company G mentioned, *"by 2030 it is agreed to reduce greenhouse gas emissions by one third"*, which creates new requirements for shipping operations, as *"they (the new regulations) are starting to establish a baseline for vessels"*. The increasing role of classification societies as regulators towards standards schemes can create directives in the shipping industry, where alliances between big industrial players could lead to standardization. Although it was noted that some companies in this sector lack the capacity to engage in large partnerships, *"we learned that we don't have the capacity to do this at the moment, and we are still more concentrating on doing our homework internally"* explained Company H. Also, Company J addressed this as an urgent matter: *"we need to use these collaborations to implement innovative solutions. And the benefit goes finally to the to the final consumer*". According to Lind et al. (2021) some are receiving support for such collaborations through initiatives which include research projects.

Companies expressed a strong perceived need for data sharing between equipment, requiring manufacturers and ship owners to allow communication between different equipment, as stated by Company I, *"Take a turbocharger as an example, a component on the engine. If the software that works on the turbocharger to assess its performance or condition, can it not use the engine data?"*. However, sharing data can present dualities. On the one hand, it can provide obstacles for companies to share customers, as they might give away elements of their competitive advantage. On the other hand, including new stakeholders is necessary in data sharing structures, for example informing insurance companies about the benefits of equipment using prescriptive directives from digital services.

In general, the adoption of digital services requires a harmonized approach where new incentive models benefit from efficiency in ports and environmental actions. Company M stated that *"Shipping is sort of compliance-driven"*, which creates complexity around driving forces from the external pressures that this industry is subject to. Compliance often leads organizations to look at environmentally beneficial options (Lister et al., 2015; Stevens et al., 2015), the examples found in the literature and the interviews include incentive models, along with other digitalization alternatives used onboard vessels. Examples of incentive models in the maritime sector, where benefits and risks are shared across stakeholders, have been found in the adoption of scrubbers and other techniques for hull ballast water cleaning (Olaniyi et al., 2018). The cases showed that the pressures to address sustainability mainly stemmed from the need for compliance with regulations.

From a political perspective, interviewees perceived the industry as operating the same way they have done for the last 20–30 years. Despite some vessels being updated, the industry is still considered rather conservative and siloed. For instance, port authorities rely on too many service providers creating data silos that complicate value chain integration. Also, open ecosystems rely mainly on third-party applications, where customers need to decide and prioritize which vessels to retrieve data from, and only in some cases, decide on costing structures such as pay-for-access, as exemplified by Company M, *"it's basically a cell service you're installing to pay for the installation and then you get access to the service"*.

The case studies also showed a strong cultural barrier to accept change. It was expressed that often new vendors and ecosystem providers attempt to dictate the market and are highly critical of previous installations. Overall, the increasing strictness of regulations might lead companies to attempt improved understanding of their vessels. Service providers will require to define value in a better way to avoid unreceptiveness from their customers towards their services. In this sense, digital maturity, and organizational factors, such as loyalty and integration, among collaborating companies have a very large impact on the adoption of digital technologies that support sustainability. Company L reflected on the dynamics between service providers and customers *"it brings more to you as a supplier because they are kind of almost fully integrated with your system, and then they use you even more on the services side"*.

The discussion on digitalization and business transformations present dualities. On the one hand, some initial collaborations were observed between ecosystems and data integrators, where companies are connecting through matchmaking and some mergers are performed to acquire specific expertise (i.e. a particular technology). In an interview, Company I mentioned that *"We are starting to create the ecosystem for this sort of collaboration, being in a good position to be integrators of data"*. On the other hand, some companies seemed reluctant to collaborate and tend to question the interest of competitors suggesting joint efforts.

Some examples of digital services that are increasingly functioning due to regulations include the adoption of more just-in-time (JIT) strategies in ships in ports, where anchorage minimization is supporting the transition towards a more automated and greener shipping sector. The interviewees foresee a future where the maritime industry needs to work towards seamless transitions by standardizing ways of working, as mentioned by Company G, *"So that's the sort of transition right is from infrastructure into integrations"*. In terms of standards, middle grounds need to be found; maximal standardization is not expected to go very far, but the lack of standards today is not allowing automated asset models.

Additionally, some companies expressed there are concerns about the governmental regulations' reactions to companies that might merge and acquire new companies that complement their lack of skills and knowledge. In this regard, acquiring and retaining talent with domain knowledge was explicitly expressed by Company C, *"(a recent graduate) it will take 10 years for him to be a project manager in a major project. So, we must retain and attract experienced talent"*.

4.2. Economic and technical

The digital servitization trend was observed in the maritime sector. In the study, the interviewed companies reflected on the need for sales incentives for digital service adoption, which require making value offers tangible. Creating strong value propositions can allow digitalization to enable new revenue streams, as Company B questioned, *"There are a lot of complex business models with different stakeholders, but in the end is down to: who is picking up the fuel bill*?" becomes highly relevant for new business models in this sector. For instance, promising higher value capture can, for some, justify increased service costs.

Changing customers' mindsets is deemed as one of the hardest activities, highlighting the need for strategy-focused leaders. The commercialization of values such as flexibility can encourage some companies to accept subscription-based services as they perceive freedom to plan their business in the medium term. Optimization software was perceived as a potential offering that could be marketed as "Software-as-a-Service", along with other service-based models. Company H forecasted, *"I would say that the subscription-based model will be the one used more and more in the future"*. Similarly, there is increasing enthusiasm around terms such as "digital twins", which sound like appealing ways of creating competitive advantage through the visualization of equipment, such terms created curiosity among the participants, who made questions such as Company L, *"And should it be technically feasible to implement the engine-as-a-service model? Would customers be willing to pay for it?"*.

A driving force for digital tools is the perception from companies that generated savings could enable capital expenditure modifications. Manufacturers will need to see data and understand how to prevent failures through prescriptive advice on real-time running equipment. However, this requires compatibility and interoperability, particularly with products such as electric engines, which the interviewees anticipate will require predictive maintenance contracts. Interestingly, the interviews also mentioned that predictive maintenance today is working in practice as preventive maintenance, meaning that the data accuracy is not considered sufficient to make decisions regarding the transition towards smart maintenance strategies.

A main driver of digital transformation is the increasing perception of value from data. However, all the aforementioned points are only feasible if data is available, and if sensors and interphases are stabilized. In their work, (Poulsen et al., 2022) reflected that collecting data such as fuel consumption, will not per se support energy efficiency; such environmental improvements depend on the complete implementation and adoption of performance monitoring systems and on the availability of time and resources for shipping organizations' data analysis. The Company I expressed that companies are basically "*…drowning in data. They are not even equipped to handle the amount of data that they are gathering, they don't have the people to analyze this data and make meaningful assessments out of it"*.

Business expansion and developing new offerings on top of companies' core businesses requires harmonic collaboration and data-sharing strategies that avoid task replication and the overuse of sensors to collect that could be shared across value chains (Aspara et al., 2011). Therefore, the quality, reliability and availability of data are critical for the definition of business models, particularly service price definition, that rely on the provision of prescriptive guidance for customers on how they operate their vessels. Company K mentioned that they foresee pricing as a difficult topic to collaborate in *"this is also a small risk, that's why we have some tough topics that are off the table"*. For instance, creating services that find value in the early detection of anomalies and proposals of solutions seemed to be highly interesting for the interviewees, but they foresee difficulties in the measurement of the obtained benefits, creating hardships around the use of outcome-based services.

A context-specific situation the discussion about the lack of availability of connectivity when at sea. Some examples of how this can be limiting were found in statements such as *"If you were to have 30 seafarers, all with two or three devices all trying to use that line, it would probably get saturated, let alone a voice chat connection!"*. This lack of connectivity and the high costs associated with the solutions currently available in the market are perceived as obstacles to the progress of the shipping industry towards digitalization.

The discussion around technical feasibility also highlights the long lifecycle of products and extended use of older vessels. Such equipment is often excluded from being able to use advanced services, as suggested by Company G *"if it's older than 15 years or 10 years, then there's a high chance it won't have any sensors on board"*. In general, there seems to be a lack of awareness of what are the technical pre-requirements for the implementation of digital technologies, and the type and quantity of in-house resources that might be required. For instance, the lack of sensors can negatively impact automation efforts, creating a high number of repetitive tasks and complicating connection to shore.

From a technical perspective, there are also hardships to integrate several systems through operational technologies. The interviewees reported that applications from different vendors are very often siloed, and companies require merging standardized and customized solutions to achieve their objectives. Such customized integrations make it rather difficult to measure with high accuracy the progress or benefits obtained from digital services, as Company G reflected, *"all of these applications are siloed and then you have to build them into the data warehouse"*. Performance measurement itself is challenging, but developing measurements with accuracy levels that can be the basis of costing methods, seems require extensive research in the maritime sector, particularly given the high variety of digital maturity across companies.

As of today, there is a gap perceived by customers in the benefits promised by some digital services and the real results. This gap brings pressures to the costs, which are often pressing the brakes on the digitalization journey of companies. Furthermore, new business models where costing methods are outcome-based are often perceived as complex, leaving customers skeptical towards the lack of control and influence on their monthly invoices.

Data gathering requires sensors, which are often considered expensive and cost-intensive parts of digitalizing older ships. Company I and G reflected on the high expenses related to retrofitting, and Company A stated that there is a lack of understanding of how to do this efficiently, a gap that could be addressed by learning methods from land-industry such as manufacturing. Investment hardships are particularly challenging for small players in the industry, who often lack resources to upgrade their equipment and invest in digitalization (Raza et al., 2023), deeming collaboration with OEMs as a beneficial alternative.

Some reflections around service provision reflected on today's business models require compromise to engage with customers, as suggested by Company H, *"When it comes to the maritime business everyone is currently struggling with budget, with OPEX and CAPEX"*. Customers can often be fearful of unsuccessful investments where capitalization takes too long. Also, Company A mentioned the importance of having good invoicing strategies to avoid creating additional reluctance from companies towards services. Such reluctance, combined with shipping being an environment with no central player who can direct change, has impacted the speed of innovation (Lind et al., 2021).

In the interviews the maritime sector was repeatedly compared to the aviation sector, with the differentiation of longer stages of development and product-usage. This presents many opportunities for product lifecycle extension, but it also poses challenges. Although increased data availability is expected to have a positive impact, Company I mentioned that *"traditional metal equipment development cycles are years long"*, which is incomparable with fast software development today, highlighting the need to integrate service and product lifecycles.

Some unexpected applications of digital servitization in the maritime sector included the use of software robotics to simplify tasks, such as automating invoicing. Also, the JIT strategies seen in the legal analysis, require transparent data sharing between stakeholders, an ambitious strategy with relevance that increases continuously. This also highlights the need for new skills in employees to be able to analyze data and create meaningful assessments through and from the use of technologies, as Company B stated, *"we need to go more and more for specialization to have experts that support the crew on board in processes and decision support"*.

Interviewees' expectations for the future of shipping included an increase in new business models, where more subscription-based approaches appear in contracts. As Company D stated that *"we also do deliver support services as a part of a subscription. We see more and more that we are going into subscription models"*. Also, although in the past maritime companies tried to build their software and invested in personalizing API management frameworks, it is expected that more established and mature software companies try to enter the market by adapting their offerings to this sector. This was highlighted by Company E, who stated: *"we have to think that the data is an asset like money would be, we have to control it, analyze it, we have to make it more"*. This might be particularly useful when redefining data agreements and customer expectations towards product-services.

4.3. Environmental and social

Environmentally, the driving forces for digitalization and new business models, such as servitization, relate to efficiency and energy consumption. Some interviewees mentioned that there is a lack of clarity on how to enforce sustainability, as in the maritime landscape many companies might not know where to start. Though, for many companies, services that support the reduction of lifecycle costs lead to a rather positive outlook that can kickstart sustainability initiatives. Company I forecasts that *"the main motivation for customers to pay for such services would be savings on lifecycle costs, as it could help eliminate surprises for them"*.

Global pressures such as the increased need for reporting to the European Union and the International Maritime Organization (IMO) are positioning new technologies as alternatives to reduce emissions. Company N mentioned that *"companies are trying to integrate systems to provide optimal navigation (…) depending on actual weather and currents to reduce consumption of fuel because it has an immediate commercial value to vessel owners"*, highlighting the need to fully understand the operational context to match sustainability initiatives. Further, Company F reflected on the shift towards sustainability, while they highlighted that they need to listen to their customers' priorities, *"we need to follow the rules that are driving for more environmentally efficient ships, but then we have a focus to go beyond what the customer wants"*.

Moreover, initiatives that aim for CO_2 reduction, require aggregated measuring of the CO_2-producing equipment onboard. As Company I said: *"In an ideal world, you would have information of all the CO_2 producing equipment on board the vessel because it's not only the main engine, it is also the auxiliary engines, the boilers and incinerators"*, highlighting the need compatibility, interoperability and communication across equipment. The documentation of environmental performance could also benefit from technologies such as digital platforms where visibility supports today's difficulties to define and implement quantitative measurements that address environmental sustainability.

From a social perspective, a main driver to adopt digitalization is to provide better living conditions to the employees while at sea. This sector, which includes employments that often requires long seasons away from home, can be hard to manage with poor connectivity available, particularly with younger generations, who have new demands in terms of communication with land and entertainment. In contrast, some employees showed rather conservative views towards the adoption of digital technologies, particularly when they do not perceive the positive impact of their implementation in the workplace. Digitalization is perceived to greatly impact human relationships, particularly in isolated working environments; as Company A mentioned, *"when I left, we were like a family because you spent half a year -minimum- on board the ship"*.

The results also highlight the need for more employees with the right skills for the handling, management, and maintenance of digital devices. This matches the concern of Company A, who stated that "*there is a very limited amount of personnel for this business globally*". Therefore, digitalization contributes to the already existing challenge for many companies of talent retention, as the experience at sea is invaluable in this market, creating hard competition. Some of the interviewees reflected on the changes perceived in maritime educational programs, such as Company A who stated that *"if you do not change the education then maybe, at a market stage you should have the open line of education between different professions"*. For instance, to upskill employees, some companies reflected on the value of smaller trainings which could take place quarterly, where employees work on improved productivity, awareness of innovative technologies and understanding of how to use technology effectively and safely. Such an approach was deemed preferable over extended periods of training.

5. Discussion

This section discusses the findings previously presented, focusing on the managerial implications, identified needs, and shifting responses in the maritime industry, as illustrated in Fig. 4. While this study focused on 13 companies in Northern Europe, many of the observations made (challenges and needs) are expected to be generalizable in the maritime sector. The authors acknowledge the limitations of this work, which relate to the focus only the maritime shipping sector and the geographical delimitation established. Future research can benefit from expanding its perspective to include additional case studies conducted in other geographical regions, and potentially engage with industrial sectors for companies operating in comparable contexts.

The three aggregate dimensions captured the results obtained from the literature review and the case studies. The political and legal aspects showed that new requirements and regulations are setting new baselines for shipping operations (Sampson and Ellis, 2015), while simultaneously including new stakeholders (e.g. classification societies) in the development of standardization tasks. In the maritime sector, which tends to be driven by compliance (Lister et al., 2015), new expectations such as increased push on CSR (Fasoulis and Kurt, 2019a,b), can push the transition towards digital servitization. Examples of servitization included new business models for the deployment of scrubbers, although some of the interviewees questioned their environmental benefits. Recent research also qualifies scrubbers as controversial (Ytreberg et al., 2022), highlighting the political tint of such implementations. For long term sustainability benefits, companies are suggested to critically evaluate the value captured and consider stakeholders carefully.

The conservative nature and cultural barriers connected to risk aversion towards new business models appeared repeatedly in the interviews, as well as in the literature (Raza et al., 2023). Interviewees mentioned that risk aversion varies between different geographical locations. It can be highlighted that there are other industrial contexts which present characteristics that are comparable to those of the maritime sector, such as the conservativeness and fragmentation mentioned by the interviewees (Sklyar et al., 2019). This is supported by the work of Burton et al. (2015), who identify new business strategies and the corresponding tensions, as required future research, particularly in the maritime sector which connects several cultures and countries with their corresponding different regulations and standards.

From the perspective of technical and economic implications, documented research found attempts to develop functioning structures for the financing of service-based offerings (Pagoropoulos et al. 2014, 2017; Rivas-Hermann et al., 2015). In practice, experts reported the increased requirements from data to develop functioning business models that increasingly service-based. However, similar to land-based industry, many companies find themselves collecting more data than ever, but lacking the technical skills and workforce capacity to process the data and convert it into value (Poulsen et al., 2022). Last, from a sustainability perspective, the maritime sector will require increasing efforts to succeed with CO_2 emission reporting and establish tangible reduction actions.

This study also described the attitudes perceived towards sustainability from industrial companies in the maritime sector, as summarized along with other insights in Fig. 4: reluctance, curiosity, optimism, and exploration. These stages are comparable to frameworks proposed in change management (Barreiro-Gen et al., 2023); unsurprising, as transitioning from traditional business models to new ones is often deemed risky to companies in an ever-competitive era.

Future research could suggest archetypes and implementation guidelines, in relation to the identified shifting attitudes, to support companies in the maritime shipping in this transition. Future empirical studies could focus on real-world applications of digital servitization and quantitatively evaluate their sustainability implications.

The overall findings of this study contribute to advance the field of digital servitization. The findings are expected to have validity beyond the Northern European Region, as they are not geographically constrained but rather dependent on technological, organizational and sectorial factors. Although the results of the case studies are for specific companies in the maritime sector, some of the findings could be transferable to other industrial sectors with similar characteristics. We encourage the research community on digital servitization to further investigate how to better support companies in other industrial sectors as they work towards their sustainability objectives.

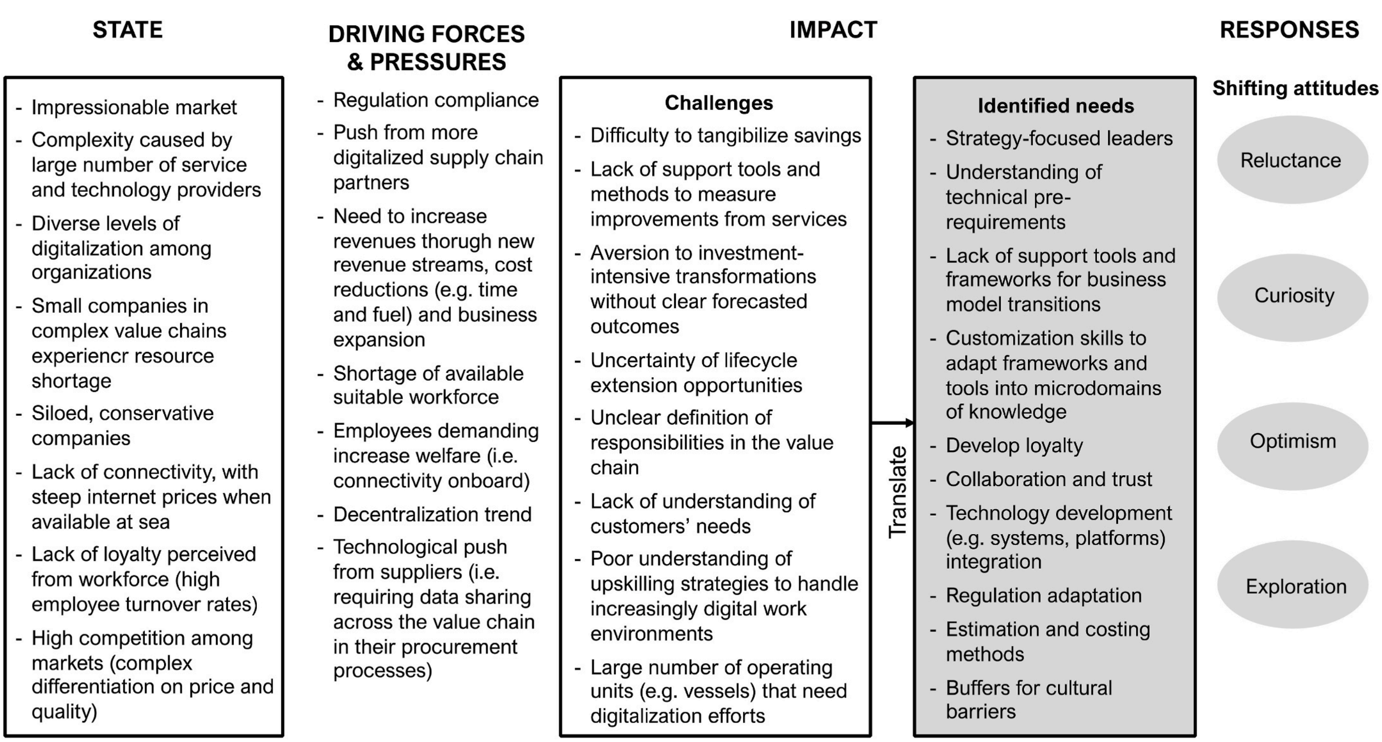

Fig. 4. Integration of case analysis.

6. Conclusions

This study investigated the state-of-the-art of digital servitization along with their implications for sustainability within the maritime shipping industry. Multiple case studies were conducted with companies in the maritime sector to integrate how servitization and digitalization relate to sustainability. The elements of digitalization that provide the highest value are shown to be in constant evolution; the role of connectivity and data capture, analysis and usage remain critical topics, along with concerns regarding technical capabilities and the impact of technologies on stakeholders across value chains. The challenges and opportunities identified will impact workforce requirements, highlighting the need for skilled employees to support digital technologies adoption and exploitation, data acquisition, usage, and implementation.

Digital servitization can support sustainability through the proposal of shared costs and responsibilities to fairly redistribute the benefits across the value chain. However, the lack of clear responsibilities and roles could hinder the prioritization of sustainability-oriented changes. The maritime industry showed a mostly reactive approach to regulations, which put pressure on companies to reduce their emissions and fuel consumption, but there is limited documentation on the promotion of activities such as retrofitting and well-informed technological investments that can support more a more sustainable maritime sector. A challenge for increased collaboration relates to the lack of awareness, proactivity, and role clarification, particularly relevant given the large number of stakeholders involved in the maritime sector, posing requirements for strong agreements on data privacy and security. Also, all interviewees referred to the maritime sector as a conservative industry that highly appreciates experience, which could represent slower transitions; though, applications such as data acquisition, processing and utilization can increase efficiency and support decision-making in vessel operation and maintenance. Further, the shortage of skilled workforce, which is familiar with both ship operations and digital technologies to capture value from technological investments, highlights the relevance of harmonizing new technologies, tasks, and the preparation of their workforce.

From a theoretical perspective, this study contributes to advancing the field of digital servitization, by documenting the driving forces, pressures, and challenges of digital servitization for sustainability based on empirical evidence of cases in the maritime sector. The approach followed in this study, which integrates the analysis of both internal and external factors to digital servitization, contributes to the call for increased case studies in the body of literature of digital servitization. Moreover, it contributes to identifying how the growing pressures from a political and organizational perspective can create shifting attitudes towards the adoption of new business models. From an industrial perspective, this study bridges theory and practice by providing a list of identified needs that can support companies adopt elements of digital servitization for a more sustainable maritime sector. Also, the narrative format of the results can support industries as they identify with a particular context.

This study provided a snapshot of the status of service-based business models in the maritime sector. Three of the companies expressed explicitly to be working towards performance-based business models. This suggests the need to further explore how companies can benefit from digital servitization to reduce the environmental impact of operations, and position sustainability at the core of the value creation and delivery processes. Restructuring business models is a complex process and requires well-designed contracts along with openness to explore value-capture while continuously appearing challenges. The shipping industry is expected to remain a key contributor in the global economy in the foreseeable future, highlighting the need for further research work and industrial development which accentuates sustainability thinking at the early stages of business model development.

CRediT authorship contribution statement

Clarissa A. González Chávez: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Selma Brynolf:** Conceptualization, Funding acquisition, Investigation, Validation, Writing – review & editing. **Mélanie Despeisse:** Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing. **Björn Johansson:** Funding acquisition, Supervision, Writing – review & editing. **Anna Öhrwall Rönnbäck:** Supervision, Writing – review & editing. **Jonathan Rösler:** Investigation, Writing – review & editing. **Johan Stahre:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Bjorn Johansson reports financial support was provided by EU funding agency Interreg Baltic Sea Region. Selma Brynolf reports a relationship with Swedish Energy Agency that includes: funding grants.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.140401.

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