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Review

Driving the Circular Economy Through Digital Servitization: Sustainable Business Models in the Maritime Sector

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Abstract: This study explores the integration of digitalization and circular economy (CE) principles within the maritime industry through a theoretical analysis, proposing a framework that aligns business models with Sustainable Development Goals (SDGs) and net-zero objectives. By investigating how digital servitization and circular business models can drive economic, social, and environmental outcomes, this research provides valuable insights into sustainable value creation and capture across maritime value chains. The theoretical analysis covers the evolution of business models, emphasizing their collective role in fostering sustainable transformation within the maritime sector. The central idea of this study is a sustainable value mapping approach that aligns product–service systems (PSSs) with circular economy principles, incorporating lifecycle thinking (LCT) to capture the full environmental, economic, and social impacts. This broader perspective on the economic value proposition highlights the need for a shift from selling products to offering servitized products, acknowledging the importance of sustainability across the entire product lifecycle. This framework offers actionable guidance for maritime stakeholders committed to transitioning their value chains towards sustainable, circular models, addressing both production and consumption dimensions to achieve broader environmental and social benefits.

Keywords: maritime value chain; ecosystem; value system; business models; sustainable value; circular economy; digital servitization; product–service system; sustainable circular business model innovation

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1. Introduction

Technological disruption is transforming the way businesses operate and how they establish connections among themselves and with customers across different levels. This shift involves not only the evolution of business models but also significant changes to value chains and networks, which are adapting to a variety of disruptive forces. For instance, business ecosystems go beyond traditional value network models by adopting a broader stakeholder perspective (Rong et al., 2018). This includes third parties affected by externalities as well as regulators working to manage these externalities, particularly the negative ones.

Building on this transformation, sustainability, circular economies (CEs), and digitalization have emerged as key focus areas for researchers, policymakers, businesses, and society at large. These concepts collectively address the need for innovative approaches to balance economic growth with environmental and social objectives. Sustainability emphasizes the integration of environmental resilience, economic development, and social inclusion to ensure well-being across generations (IISD, n.d.). At the same time, CE promotes the creation of resource-efficient economic systems by reducing material and energy waste, while digitalization facilitates this shift by enabling transparency, optimizing resource use, and driving innovation (Hariyani et al., 2024).

Embedding circular economy principles across value chains, such as in the maritime industry, not only reduces environmental impact but also enhances economic and social value creation. This alignment with the UN's Sustainable Development Goals (SDGs) promotes responsible resource management, supports sustainable communities, and strengthens resilience against environmental and regulatory challenges (UN, n.d.).

To support this transition, the European Union has introduced ambitious regulatory frameworks such as the European Green Deal Plan (European Commission, 2019), the EU Taxonomy (European Commission, 2020a), and the Circular Economy Action Plan (European Commission, 2020b). These initiatives aim to accelerate sustainability and economic transformation. However, while these policies set a strong foundation, challenges persist—especially at the micro level, where manufacturing companies struggle to adopt CE practices. Furthermore, the broader application of CE principles at the macroeconomic level remains limited, underscoring the need for continued efforts to bridge this gap.

For sustainability-oriented innovation to create meaningful impact, it must transcend isolated, incremental improvements and instead drive comprehensive, organization-wide transformations that extend to the broader stakeholder network. This requires integrating sustainability into all aspects of business operations and fostering collaboration across the entire value chain for sustainable and shared value creation (Porter & Kramer, 2011). This shift towards creating shared and sustainable value underscores the emergence of the shared economy and the circular economy, both of which require digital solutions to facilitate the transition and enable new business models. For instance, the Digital Product Passport (DPP) is a critical element of the European Union's Circular Economy Action Plan that was designed to enhance sustainability by improving the flow of information across supply chains (European Commission, 2022).

A notable early example of a DPP in maritime applications is Maersk Line's cradle-to-cradle passport, introduced in 2011 for its Triple-E container vessels. By outlining procedures for material disassembly and recycling at the end of a vessel's 30-year service life, Maersk Line showcased how DPPs can apply circular economy principles to promote sustainability in the shipping industry (SSI, 2021). Another example is Malmö Port (CMP), which adopted circular principles by managing cruise ship waste in a port-operated biogas plant, generating clean electricity while enhancing energy security (PEMSEA, 2022). Meanwhile, in the shipyard sector, Green Yard Kleven recycles steel from decommissioned ships, repurposing materials for other industries. A notable example is the offshore ship Normand Borg, whose hull sides were transformed into the foundation for a water park in Oslo (Green Yard, 2021). Hence, a cost–benefit analysis of the circular model highlights advantages such as reducing negative externalities, generating revenue from electricity sales to ships, managing waste within the port area, and selling the resulting fertilizer to the agricultural sector.

Digital technologies are not only complementary tools but also central to this evolution, forming the foundation of a new paradigm—sustainable business model innovation (Fuerst et al., 2023). As a result, it is no longer sufficient to consider circular or shared business models in isolation. Instead, they must be viewed as integral components of comprehensive sustainable circular business model innovation that leverage technological advancements to achieve long-term economic, social, and environmental goals (Brenner & Drdla, 2023).

However, one of the primary obstacles to BM implementation is the uncertainty surrounding the long-term sustainability benefits of such a transition, and the limited awareness and understanding of the benefits associated with CE principles among stakeholders in the maritime sector present significant challenges to their widespread adoption

(Okumus et al., 2024). Moreover, the concept of a circular economy is not fully understood within the maritime industry, where discussions often default to the recycling stage (Agarwala, 2023). However, the current methods employed in ship recycling yards significantly limit the industry's ability to fully adopt CE principles and harness the potential of R-strategies—such as redesign, reduce, reuse, remanufacture, repair, and recycle—to drive sustainability (Okumus et al., 2023). While recycling is widely practiced, it occupies the lowest level in the end-of-life (EoL) hierarchy within the CE framework (MacArthur, 2013; Gilbert et al., 2017), offering limited opportunities to maximize resource efficiency and extend the lifecycles of materials.

To address these limitations, this study explores the broader potential of circular business models (BMs) within the maritime domain, focusing on aligning digitalization with circular economy principles. Specifically, it examines sustainable value mapping approaches and investigates how emerging technologies can enable circular and digital servitization scenarios. Two key research questions are posed: *How do digitalization and a circular foundation transform business models? And what shifts in the business ecosystem result from this transformation?*

The objective is to analyse the evolution of business models and changes in the business ecosystem, showcasing how emerging technologies drive these changes while promoting sustainability through the circular economy framework. In this context, understanding sustainable value creation becomes essential.

2. Sustainable Value Creation Concepts

Value creation within a company is commonly described as "the gap between revenues and expenses" or as the "value chain" component of its operations (Lüdeke-Freund et al., 2020). This sets the stage for examining the "value chain" concept and its evolution.

2.1. Evolution of the Value Chain Concept

The "value chain" concept is a widely used approach for understanding business processes and optimizing business operations. It provides a comprehensive view by examining the organization from a supply chain perspective, focusing on how each activity contributes to overall value creation, delivery, and capture. The term "supply chain" refers to the integration of all activities involved in sourcing, procurement, production, and logistics, while the "value chain" encompasses a series of business operations where value is added to goods and services to enhance customer satisfaction.

Hence, the Supply Chain connects all functions, starting from the transformation of raw materials into finished products and ending when the product reaches the final customer. Meanwhile, the Value Chain is a sequence of activities focused on creating or adding value to a product.

Value Chain. The concept of the "value chain" was introduced by Porter (1985) to describe the entire range of activities necessary to bring a product or service from its initial conception through various stages of production and distribution and to its final consumption and disposal. As a product moves through the different stages of the chain, it is assumed to gain value (Hellin & Meijer, 2006). The value chain serves as a tool for breaking down a business into its key activities, which can help identify sources of competitive advantages (Brown, 1997). Over time, this concept has been widely discussed in economic and management literature (Abecassis-Moedas, 2006).

The value chain, as defined by Porter (1985), consists of value activities and margins (Figure 1).

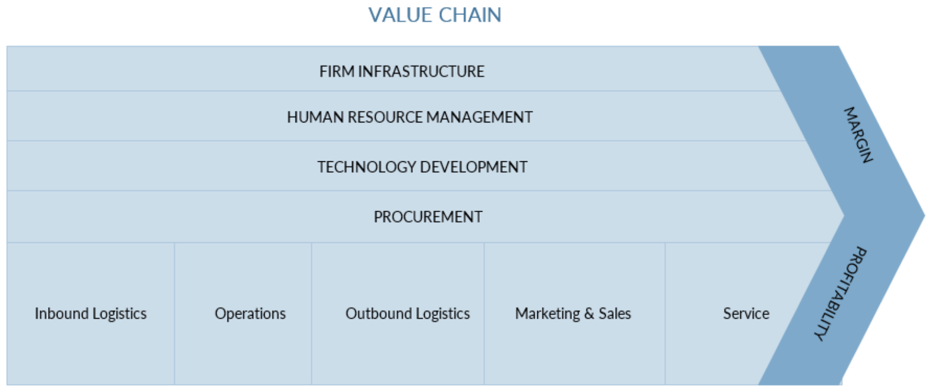

Figure 1. Value Chain Configuration (adapted from Porter, 1985).

It categorizes value activities into two main groups: primary and support activities. The primary activities consist of inbound logistics, operations, outbound logistics, marketing and sales, and service, whereas the support activities include firm infrastructure, human resource management, technology development, and procurement. The margin is defined as "the gap between the total value generated and the cumulative cost of executing these activities." The Figure 1 shows all the entities in a company's extended supply chain and illustrates all value-adding activities performed by each organization along the chain.

In addition, according to Er and MacCarthy (2002) chain configuration not only outlines the structure but also addresses the nature of coordination and interactions among its members. Moreover, Walters and Rainbird (2004) note that the value chain can be analysed at two distinct levels:

- At the strategic (macro) level, value chain analysis helps determine a firm's position within the market and identify key industry drivers.
- At the operational (micro) level, it involves examining the actual processes occurring within the firm, often referred to as operational management.

Value System or Value Network. The real potential of value chain analysis lies not only in understanding the micro and macro factors but also in synthesizing these perspectives to gain a holistic view of the organization. Indeed, due to the complexity of relationships within modern supply chains, it is more appropriate to refer to a supply network rather than a simple linear chain. Supply chains now involve multiple stakeholders and are becoming increasingly complex and dynamic, challenging the traditional view of a linear chain. Instead, scholars advocate for a more radial, interconnected perspective of supply chains as networks. A "supply chain collaborative network" is better described as an integrated network of entities interacting within a business environment, including suppliers, manufacturers, distributors, retailers, and customers (Lam et al., 2008). Harland (1996) supports this notion, suggesting that a supply chain is more accurately described as a network of cooperation among these various stakeholders (Figure 2).

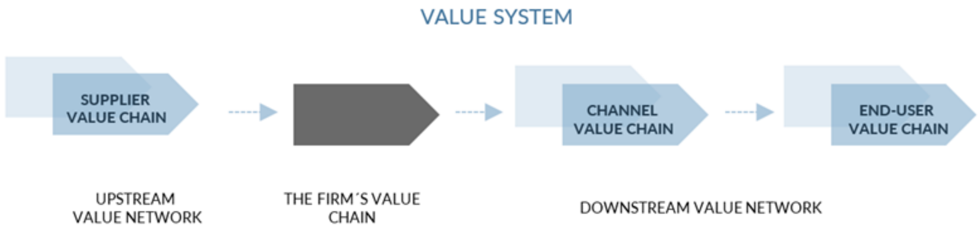

Figure 2. Value System/Value Network Configuration (adapted from Porter, 1985).

This broader network approach enhances the ability to manage the relationships and interactions required for modern supply chains to function effectively.

Hence, some scholars have started to differentiate between when to use the terms "chain" and "network". For example, Borch and Roaldsen (2007) argue that incorporating multiple value configurations, such as value chains and value networks, reflects the understanding that firms systematically differ in how activities are interconnected based on their distinct approaches to value creation. To conclude, over time, the concept introduced by Porter has evolved, incorporating new elements and being compared to the broader concept of the value network, which is considered more representative of how value is currently created within companies (Allee, 2000; Bovel & Martha, 2000; Fjeldstad & Haanaes, 2001; Normann & Ramirez, 1993; Peppard & Rylander, 2006; Stabell & Fjeldstad, 1998).

Business ecosystems. Business ecosystems extend beyond traditional value network models by incorporating a broader range of stakeholders, including third parties impacted by externalities and regulators tasked with managing these effects, particularly the negative ones. The concept of value systems or networks spans the entire chain from raw material suppliers to end customers (Porter, 1980). Although widely discussed in academic management literature, the term "ecosystem" often lacks a precise definition (Adner, 2017; Moore, 1993). Figure 3 presents visually that the value system integrates raw material suppliers, component suppliers, system suppliers, solution providers, operators, and end customers (Kohtamäki et al., 2019), and it exists within value systems.

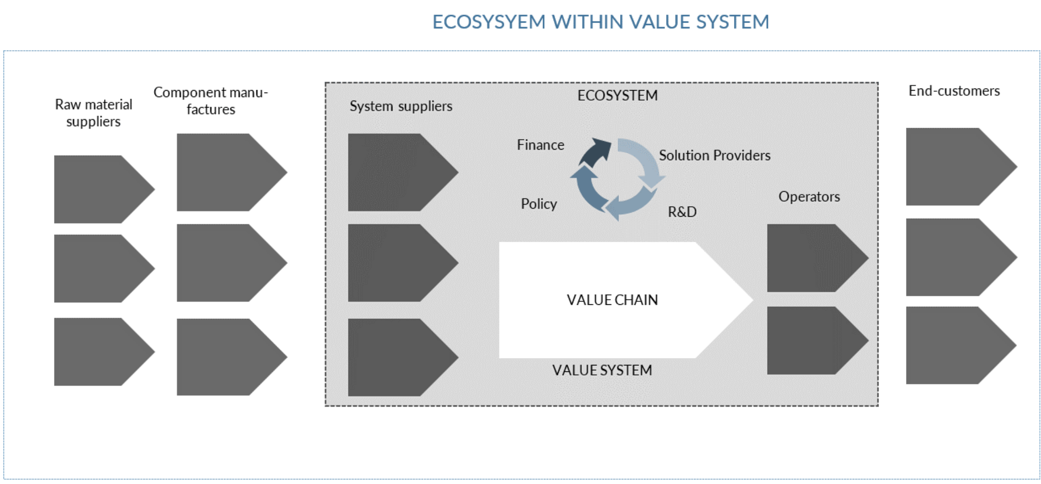

Figure 3. Ecosystem Configuration within Value Systems (developed based on Kohtamäki et al., 2019).

This progression reflects a shift in the study of inter-organizational relationships, moving from a focus on individual firms to a broader scope that encompasses supply chains, value chains, and the comprehensive frameworks of business ecosystems and value systems (Rong et al., 2018).

2.2. Value Creation Ontology

In addition to the traditional methods of creating and maintaining competitive advantage—such as effective market positioning (Porter, 1980), leveraging valuable resources (Barney, 1991), or capturing short-term gains from innovation (Teece et al., 1997; Verbeke et al., 2017)—the past two decades have seen increased focus from management scholars and practitioners on the organization of a firm's internal activity system. This system, defined as a business model, plays a crucial role in translating competitive advantage into tangible shareholder value. A business model serves as a blueprint for how a company operates and creates value.

An effective business model integrates different values, aligning them with the company's strategic initiatives to drive success, and sustainable value creation lies at the intersection of the shared interests of customers, stakeholders, organization, and society:

- **Customer Value:** Delivering a compelling value proposition that addresses the needs and expectations of the end user. According to Kotler (2003), customer value increases with higher quality and better service, while it decreases with an increase in price.
- **Business Value:** Generating returns for shareholders and ensuring the financial sustainability of the organization.
- **Stakeholders Value:** Enhancing value within the supply chain through cooperation and shared benefits among stakeholders. Walters and Lancaster (2000) introduce this concept that is also called *Corporate Value*, which suggests that the objectives of all stakeholders must be met or optimized through negotiation alongside the goals of the customer.
- **Societal Value:** Promoting value creation that benefits society, including managing negative externalities through corporate social responsibility (CSR) and compliance with regulations. The concept, also known as Shared Value, was proposed by Porter and Kramer (2011). This approach emphasizes that businesses can achieve economic success while actively improving social and environmental conditions in the communities they serve.

To gain a clearer understanding of the logic behind value creation, delivery, and capture—core components of business models (BMs)—it is crucial to analyse how value is generated, conveyed, and perceived throughout the business model. Addressing the concept of "value added" first helps clarify these foundational aspects, offering insight into how business models deliver value not only to the company but also to its customers and stakeholders.

The concept of added value, as defined by De Chernatony et al. (2000) and Brandenburger and Stuart (1996), refers to the value created by all participants in a supply chain, minus the value generated without a specific player. This value distribution is crucial for maintaining stakeholder engagement and confidentiality in operations. For measuring added value, Kay's (1993) approach suggests calculating it by subtracting operating expenses and the cost of capital from revenues. If positive, the organization adds value; if negative, it destroys value. The formula is as the follows:

$$\textit{Added value} = \textit{Revenues} - (\textit{Labor costs} + \textit{Material costs} + \textit{Services costs} + \textit{Capital costs}). \quad (1)$$

Economic Value Added (EVA) and Economic Profit. Another widely used formula is Economic Value Added (EVA). Economic Value Added (EVA) is a value measurement technique developed by the consulting firm Stern Stewart and Company (Stern, 1985; Stern et al., 1995; Stewart, 1991). This method evaluates a company's ability to generate value beyond its cost of capital, serving as an indicator of financial performance and value creation. In other words, it measures shareholder value by considering Net Operating Profit After Tax (NOPAT) minus the cost of capital employed:

$$\text{EVA} = \text{NOPAT} - \text{WACC} \times \text{K}, \quad (2)$$

where NOPAT—Net Operating Profit After Tax or EBIT × (1 − Tax Rate),

WACC—Weighted Average Cost of Capital, and
K—capital employed.

Here, EVA is widely used as a recommended measurement method to assess the effectiveness of value chain reconfiguration decisions. Hence, EVA, calculated as the firm's turnover minus its operating and capital costs, is considered equivalent to the concept of "margin" in Porter's value chain framework (Figure 4). Consequently, an improvement in EVA would reflect an expansion of the firm's margin, thus increasing its competitive advantage.

Hence, EVA is a financial metric that measures whether a company is creating or eroding value within a given period. It is calculated by subtracting the capital charge (determined by multiplying the cost of capital with the invested capital) from the profit generated by the investment. The term "economic profit" is frequently used as a synonym for EVA.

Business Valuation. In business valuation, the growing perpetuity formula is often applied to estimate the continuing or long-term value of a business. This method assumes a company will operate indefinitely with cash flows growing at a steady rate (g). However, it has certain limitations, as it can overstate the trend in a company's performance, potentially leading to an inaccurate assessment of its long-term value.

$$Value = Cash\ Flow/(WACC - g), \tag{3}$$

To mitigate the limitations of the growing perpetuity formula, McKinsey developed the key value driver formula. Value creation hinges on three key factors: growth rate (g), return on invested capital (*ROIC*), and weighted average cost of capital (*WACC*), in conjunction with net operating profit after tax (*NOPAT*). Value is consistently generated when ROIC improves. However, growth only contributes to value creation when ROIC surpasses WACC. With simplified assumptions of constant growth and ROIC rates, this relationship is encapsulated in McKinsey and Co's "value driver formula" (Wessels et al., 2020):

$$Continuing\ Value = NOPAT\ t = 1 \times (1 - g)/(WACC - g). \tag{4}$$

Total Value Created (Customer and Stakeholder Value). Notably, value in a business context can manifest in various forms depending on the stakeholder. For consumers, value is represented through "subjective appreciation" and "satisfaction" derived from interactions with the firm, while for owners, it is reflected in "profit" and "growth in stock prices". However, these are not the only groups expecting to capture value (Biloshapka & Osiyevskyy, 2018). A broader view must consider all key stakeholders, both internal (e.g., employees) and external (e.g., partners and suppliers along the value chain). Hence, opportunities to increase the margin must be seen and then managed in a manner that maximizes the benefits for all players in the value chain.

Management scholars and practitioners widely use the following concepts: value creation and value capture. These functions outline how a business generates value through its offerings and how it effectively captures that value to achieve profitability and sustain its operations. Based on Chesbrough and Rosenbloom (2002), to enhance business efficiency and cost-effectiveness, a well-established business model framework helps outline how a company creates and captures value.

Importantly, before value can be captured by any stakeholder, it must first be created within the firm's business model. The value-based theory of strategy (Brandenburger & Stuart, 1996) is particularly useful in explaining this process. The value stick (Figure 4) is built from four key elements: willingness to pay (WTP), price (P), cost (C), and willingness to sell (WTS).

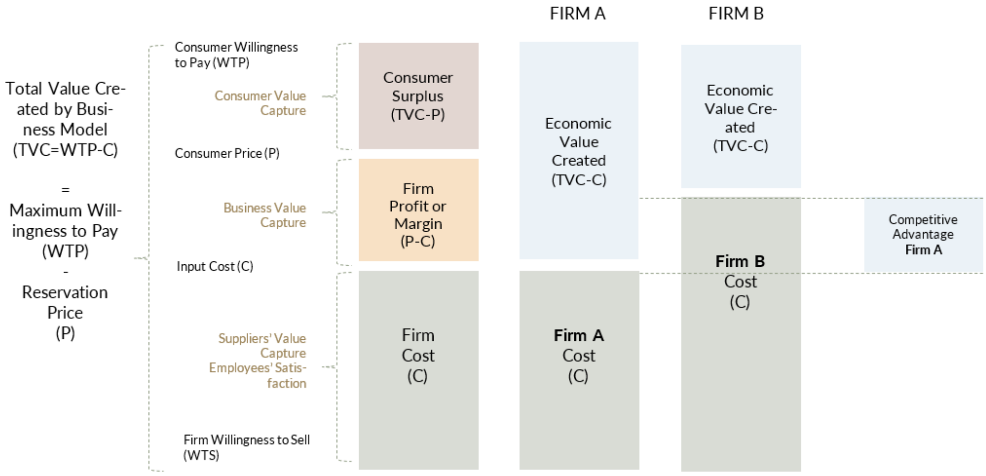

Figure 4. Business Model Value Created and Captured (developed based on Brandenburger & Stuart, 1996).

The positioning of these elements along the stick shows how value is divided among the firm, its customers, and its suppliers in each transaction. Understanding WTP is crucial because it directly influences how value is perceived and captured, determining the firm's ability to generate competitive advantage and sustain long-term growth.

According to this theory, a business model's Total Value Created (TVC) is defined as the difference between the consumers' aggregated willingness to pay (WTP) for the firm's products or services and the firm's total cost of acquiring inputs from its suppliers (C):

$$TVC = WTP - C, \quad (5)$$

Figure 4 shows that Firm A has a competitive advantage over firm B because it has lower costs. Thus, the model is useful to strategists in that it enables them to explore various ways of establishing competitive advantages over rival firms and increasing profit potential. This framework helps clarify how businesses can strategically balance value creation for consumers while capturing value for themselves. The value creation process varies depending on whether it is targeted at an individual, an organization, or society (Lepak et al., 2007).

To optimize value capture for stakeholders and customers, Hinterhuber's (2002) proposes "virtual value chain orchestration", a comprehensive approach with six key steps:

1. Internal Value Chain Analysis: Assess costs and value added at each stage of the organization to identify internal efficiencies.
2. Flow of Goods and Total Value Analysis: Quantify the value created by both upstream and downstream industries that interact with the product. This step can be further evaluated using metrics such as Economic Value Added (EVA) or Earnings Before Interest and Taxes (EBIT).
3. Identify Value Creation Opportunities: Enhance value by improving product quality or reducing costs at every stage of the extended value chain.
4. Network Configuration: Establish strategic partnerships with other companies to optimize the delivery of potential value to customers.
5. Capture Created Value: Utilize strategic alliances, joint ventures, or acquisitions to secure and maximize the value generated.
6. Cross-Industry Value Chain Management: Effectively coordinate activities across industries to optimize value creation and capture for sustainable growth.

This strategic approach helps firms align their internal competencies with external opportunities, thereby enabling enhanced value capture and long-term competitive advantages. By integrating these steps, businesses can adapt to a rapidly changing environment, aligning traditional models with evolving external factors.

Additionally, drawing on Treacy and Wiersema's (1995) framework of value disciplines, firms can differentiate themselves by adopting one of three key strategies: product leadership, customer intimacy, or operational excellence. In the context of modern digital platforms, a fourth discipline—network orchestration—has emerged, addressing the complexities of today's business dynamics (Korver, 2019). This expanded framework more effectively captures the nuances of modern business models, allowing for a balanced approach that addresses both traditional and emerging strategies.

3. From Linear to Sustainable Circular Business Model Innovation

3.1. Business Models Evolution

The concept of the business model (BM) originated in the 1970s, and it was initially associated with system modelling within the field of information technology. Over time, particularly from the 1990s onwards, the BM construct has evolved and matured, drawing on perspectives from various fields, including technology, organization theory, and strategic management (Wirtz et al., 2016). Currently, the BM is defined as the design or architecture through which a business creates, delivers, and captures value (Teece, 2010). In other words, it provides a framework for understanding how a company operates.

BM frameworks commonly centre around the concept of a value-creation logic within a reference system, such as an organization, value chain, or industry sector, and they can be represented by different elements (Wirtz et al., 2016). Figure 5 illustrates that for a company to achieve optimal value generation, each of the highlighted elements must be strategically aligned. This alignment ensures that internal operational efficiency and external market success are cohesively integrated, forming a unified value generation strategy (Johnson & Scholes, 1999).

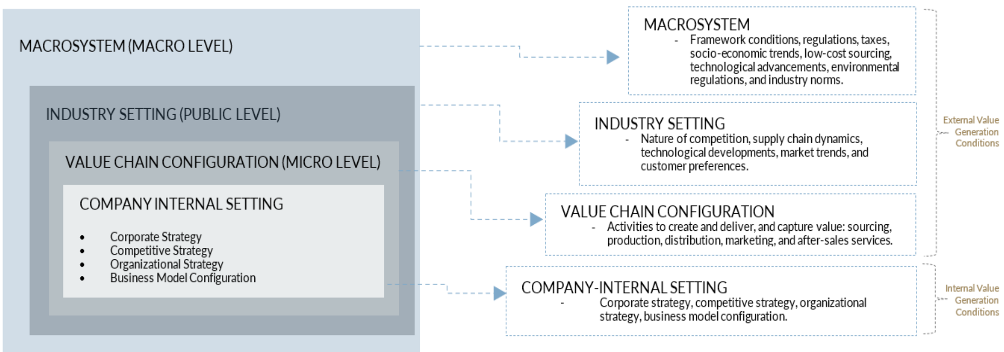

Figure 5. Company's External and Internal Value Generation Conditions.

In the context of integrated reporting, a business model (BM) is defined as a company's system of transforming inputs through its activities into outputs and outcomes that support its strategic goals and generate value in the short, medium, and long terms (IIRC, 2018). One of the most widely adopted BM representations is the business model canvas, which categorizes value generation into nine building blocks across four pillars: "product/value proposition", "financial aspects", "customer interface", and "infrastructure management" (Osterwalder et al., 2005).

1. Value Propositions: The benefits and value offered to customers.
2. Target Customers: The specific customer segments the business aims to serve.
3. Distribution Channels: The means used to deliver value to customers.
4. Market Relationships: The interactions and relationships established with customers.

5. Value Configuration: How resources and activities are organized to create value.
6. Core Competency: The unique strengths and capabilities of the business.
7. Partner Network: The external partners that support the business model.
8. Cost Structures: The expenses incurred to operate the business model.
9. Revenue Model: The way the business generates income.

Hence, this framework is built upon on the following pillars (Koilo, 2024):

- Value Capture (revenue model): Why do we use this business model?
- Value Delivery (operating model): How do we deliver the value?
- Value Creation (market model): Who is at the centre of each business model?
- Value Proposition (value model): What is offered to the client to meet their needs?

3.1.1. Business Model Innovation (BMI)

In parallel, the concept of business model innovation (BMI) has emerged, defined as the process of modifying or reinventing a BM through actions such as creating, diversifying, acquiring, or transforming the existing model in response to internal and external drivers (Foss & Saebi, 2018; Geissdoerfer et al., 2018). From this perspective, BMs can serve either as (1) enablers of strategic changes in innovation processes (e.g., new products/services) or (2) sources of competitive advantage, with the BM itself acting as the primary innovator (Boons & Lüdeke-Freund, 2013).

Important to mention, with the growing emphasis on environmental awareness, sustainability has become a crucial element of business model innovation as organizations seek greener solutions (Bocken et al., 2014). The necessity of generating value through a triple-bottom-line approach compels companies to rethink their strategies and implement BMI (Clinton & Whisnant, 2019). Hence, business model innovation (BMI) has recently gained heightened attention, particularly in areas such as sustainability, circular economy (CE), servitization, and digitalization. Each of these fields has distinct characteristics and requires tailored strategic approaches, leading to the formation of various "sub-streams" of research and application (Foss & Saebi, 2018).

3.1.2. Sustainable Business Model Innovation (SBMI)

The emerging focus on integrating sustainability into business models has paved the way for the development of sustainable business model innovation (SBMI), highlighting the increasing demand and opportunities for sustainability-oriented practices within business frameworks. According to Joyce and Paquin (2016), the "Triple Layered Business Model Canvas" is a framework designed to support sustainability-oriented business model innovation. It enhances the original business model canvas by introducing two additional layers: an "environmental layer" based on a lifecycle perspective and a "social layer" rooted in a stakeholder perspective. Thus, the model requires a broader understanding of value (sustainable value) that also integrates social and environmental objectives (Bocken et al., 2013; Evans et al., 2017):

1. Economic Value Proposition: Traditionally centres on customers acquiring ownership of the product, with the company's revenue relying on the sale price and a standard two-year warranty (Barquet et al., 2011). However, transitioning from selling products to offering servitized products requires a broader perspective on the economic value proposition, incorporating lifecycle thinking. This shift involves considering the product's use phase, and tools like Total Cost of Ownership (TCO) can provide a more accurate picture of actual costs by accounting for expenses related to acquisition, use, and disposal (Ellram, 1995).

2. Social Value Proposition: This aspect has often been linked to the principle of "doing less harm" and adhering to compliance standards, which are traditional elements of corporate social responsibility (CSR).
3. Environmental Value Proposition: Traditionally, the environmental aspect of a business model focuses on using Lifecycle Assessment (LCA) to evaluate the environmental impacts of a product or service and improving environmental performance (e.g., Joyce & Paquin, 2016).

Hence, true sustainability involves the balanced integration of the ecological, economic, and social dimensions, addressing the triple bottom line (e.g., Weidner et al., 2021). Such a shift promotes a multi-stakeholder approach (e.g., Freeman, 1984), focusing on reducing adverse effects and proactively generating positive outcomes for society and the environment. This extended view recognizes that sustainability issues often emerge from indirect supply chain relationships and proposes that firms should actively collaborate with suppliers to address these challenges. By doing so, a majority of studies shift the focus of value creation from individual firm–stakeholder relationships to a network-based approach, emphasizing the need to manage indirect relationships for sustainable outcomes. For example, Norris et al. (2021) addressed a gap in the sustainable business model (SBM) literature by integrating sustainable supply chain management with SBM concepts. Notably, the relevance of sustainable business models (SBMs) from a supply chain perspective has gained increased significance in light of the evolving landscape of sustainability reporting across the European Union. For instance, research by Long and Young (2022) emphasizes that leading firms play a critical role in reducing greenhouse gas (GHG) emissions but often miss out on opportunities for sustainable value creation within their strategies. Thus, by considering the business model as a system of interconnected activities, firms can pinpoint areas where changes can be made to optimize processes and improve sustainable outcomes (Zott & Amit, 2010). Furthermore, by adopting sustainable BMs, companies can align their operational objectives with the ESRS requirements and broader EU sustainability goals.

3.1.3. Circular Business Model Innovation (CBMI)

The current development highlights the urgent need to create new circular business models and manufacturing systems that ensure both economic and ecological sustainability for present and future societies (Rashid et al., 2013). Circular economy business models have been identified as key enablers for companies transitioning towards more sustainable and circular practices (Nußholz, 2018). Geissdoerfer et al. (2020) defined circular business model innovation (CBMI) as involving cycling, extending, intensifying, and/or dematerializing material and energy loops. The potential of further development of the new sustainable innovative business models is explored by Sposato et al. (2017), who examine how the sharing economy (SE) can support circular economy (CE) strategies by promoting sustainable consumption and optimizing resource use (Carlborg et al., 2024). Through the application of lifecycle thinking (LCT), the study illustrates how sharing economic practices can contribute to waste prevention and resource valorization, thereby reinforcing CE goals. Similarly, Dabić et al. (2024) provide an overview of Sharing Economy Business Model Innovation (SEBMI) as a part of CEBMs and its implications for market dynamics, digital technology, and sustainability. Their research highlights the complex and multidimensional nature of the sharing economy, emphasizing the need for a structured approach to understanding its impact on sustainability.

The majority of business model literature has largely overlooked the circular economy, leading to the emergence of a distinct body of research focused specifically on circular and sustainability-oriented business models (e.g., Antikainen & Valkokari, 2016). Literature reviews (e.g., Bocken et al., 2014; Geissdoerfer et al., 2018, 2020) examining circular and sustainable business models have struggled to establish a consensus on the definitions and frameworks of these two concepts. Indeed, the terms "sustainable business model (SBM)", "sustainable business model innovation (SBMI)", "circular business model (CBM)", and "circular business model innovation (CBMI)" have been frequently utilized; however, it is important to recognize that there are no singular or absolute forms of these models. The primary drivers for CE-oriented BMI include resource efficiency, resource longevity, and fostering economic growth while navigating natural resource constraints (Geissdoerfer et al., 2020), which is in line with S-oriented BMI (Figure 6).

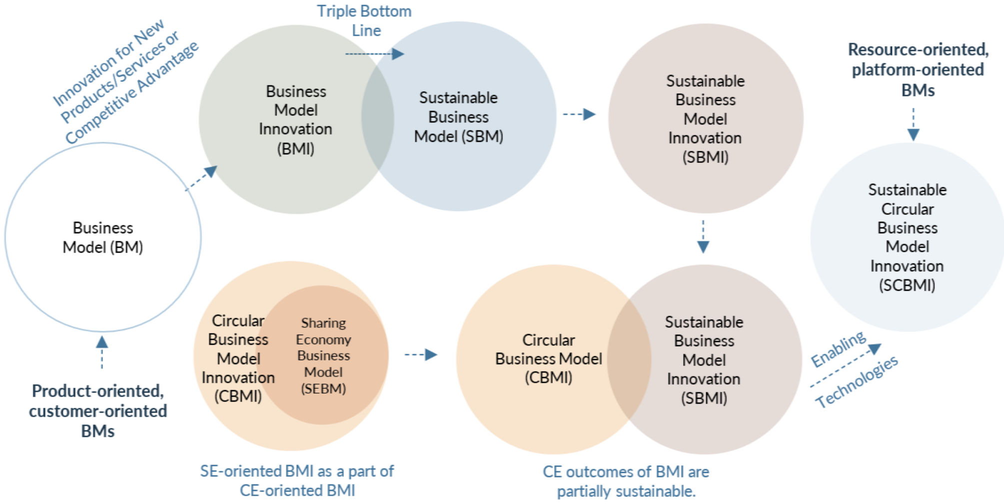

Figure 6. Evolution of Business Models Based on Geissdoerfer et al. (2020), Shakeel et al. (2020), and Chiappetta Jabbour et al. (2020).

It is important to mention that CEBMI can have negative outcomes; they emerge if only partial circularity measures are implemented, such as focusing solely on downstream circularity. For instance, a business might prioritize offering customers access to cheaper products through pay-per-use models but neglect upstream design aspects like closed-loop logistics, leading to unsustainable practices such as overconsumption or rapid product obsolescence. Conversely, S-oriented BMI places a strong emphasis on social impact and considers trade-offs in the economic domain. This means that business strategies might prioritize longevity and sufficiency (e.g., sustainable production/consumption practices) over rapid profit maximization to ensure long-term positive environmental and social impacts (Pieroni et al., 2019). In summary, the circular economy introduces significant business opportunities for both established and emerging companies. It relies on two interconnected supply chains, a forward chain and a reverse chain, where recovered products re-enter the forward chain to be reused or recycled (Wells & Seitz, 2005). This creates new market potential for businesses offering solutions along the reverse cycle. These new opportunities in the form of service business models are positioned as a superior approach within a circular economy framework, shifting focus from ownership to providing access and performance. As Tukker (2015) highlights, retaining ownership enables providers to extend product lifespans and reduce environmental impacts through improved efficiency. These developments establish a strong foundation for advancing sustainable circular business model innovation (SCBMI).

3.1.4. Sustainable Circular Business Model Innovation (SCBMI)

The digitalization and servitization of manufacturing lead to competitive advantages through innovative digital business models, which can be called sustainable circular business model innovation (SCBMI). Specifically, SCBMI encompasses the entire product lifecycle, adopting a cradle-to-cradle approach where materials are continuously reused and recycled rather than disposed of (Hoang & Böckel, 2024). Furthermore, SCBMI extends beyond individual firms and often involves restructuring entire value chains and ecosystems. Examples of sustainable circular innovation in value creation and delivery include adopting new technologies to improve resource efficiency, redesigning transportation systems, and enhancing labour conditions and workers' rights; these initiatives also require firms to extend their focus beyond their own operations and consider the broader needs of local communities and stakeholders. This approach calls for incorporating the "systems change mindset" found in Level 4 of the CapSEM Model, promoting a holistic view of sustainability across the entire ecosystem (Fet et al., 2023). Hence, SCBMI, which is gaining significant attention, warrants further exploration in terms of conceptual foundations, ecosystem transformation, and potential applications in industries such as the maritime industry. These topics will be explored in the following sections.

4. Framework for a Sustainable Circular Business Model: Maritime Industry Case

4.1. Sustainable Circular Business Model Foundations

It is evident that addressing current challenges and advancing towards a circular economy model will require radical innovations and disruptive business models. Industry 4.0 (I4.0) and the Circular Economy (CE) have emerged as two of the most widely discussed topics in recent decades, capturing the attention of policymakers, practitioners, and scholars globally (Rosa et al., 2020). The article by Chauhan et al. (2022) examines the intersection of the circular economy (CE) and digital technologies through a systematic review. The study highlights how digital tools like IoT, AI, blockchain, and big data can facilitate CE transformation by enhancing resource efficiency and promoting sustainable practices.

For example, CE focuses on narrowing, slowing, and closing resource loops and aims to improve the balance between the economy, environment, and society (Bocken et al., 2016a, 2016b). Incorporating CE principles into business model development necessitates rethinking the value-creation logic (Nußholz, 2017). Hence, as CE is increasingly serving as a key framework for sustainable development, the economic, social, and environmental benefits it offers become more crucial to understand and demonstrate (Kristensen & Remmen, 2019). It should be mentioned that a key aspect of sustainable circular business model innovation is to innovate value proposition by incorporating different circular strategies at all lifecycle stages of the product (Nußholz, 2017). Moreover, those 10R strategies of CE (SINTEF, 2020) can be effectively incorporated at the product level and can be considered at the process and system levels as well (Lugnet et al., 2020).

From Table 1, the following guiding principle of R-strategies in maritime can be derived: the goal is to increase circularity (transition from linear (R9) to a more circular (R0) economy) by using fewer resources and minimizing the environmental impact throughout the entire product lifecycle (i.e., ship lifecycle):

- R0: Refuse: Avoiding the use of hazardous materials, substituting some materials with a radically different product.
- R1: Rethink: Maximizing the efficiency of product usage through shared consumption models or multifunctional products.
- R2: Reduce: Minimizing resource and material usage and prolonging the lifetime.
- R3: Reuse: Reusing parts during maintenance and recycling.
- R4: Repair: Restoring the functionality of broken or faulty products to their original state.
- R5: Refurbish: Enhancing or updating parts during operation, maintenance, and recycling.

- R6: Remanufacture: Taking components from used parts and utilizing them to produce a new product with similar functionality.
- R7: Repurpose: Reimagining discarded parts or their components to serve a new function.
- R8: Recycling: Converting materials to regain original quality/into materials for alternative uses.
- R9: Recover: Recovering energy from used materials.

Table 1. 10R Circular Economy Strategies and Maritime Company Prioritization.

Strategy			Phase						
			Design	Raw Material Processing	Component and Equipment Manufacturing	Assembly and Integration	Operations	Maintenance and Upgrade	Dismantling
Short loops	Smarter creation and use of products	R0	✓	✓	✓	✓	✓	✓	
		R1	✓	✓	✓	✓	✓	✓	
		R2	✓	✓	✓	✓	✓	✓	
Medium loops	Extending the lifespan of products and parts	R3						✓	✓
		R4						✓	✓
		R5						✓	✓
		R6						✓	✓
		R7						✓	✓
Long loops	Useful application of materials	R8							✓
		R9							✓

Over the past decade, more than one-third of global CEOs have integrated circular economy strategies into their business models, positioning them as core components of their sustainability efforts (The UN Global Compact, 2016).

OECD (2019) classified five main circular business model (CBM) types:

1. Circular Inputs: Replaces conventional inputs with bio-based, renewable, or recovered materials to minimize resource consumption.
2. Sharing Models: Maximizes the utilization of underused consumer assets by facilitating shared access. Well-known examples include platforms like Airbnb and Uber, where private individuals share assets such as homes and cars for payment.
3. Product as a Service (PaaS) or Product–Service Systems (PSSs): Combines a physical product with a service component, where ownership remains with the supplier. Customers pay for the use or function of the product rather than purchasing it outright.
4. Product Life Extension: Focuses on extending the lifespan of products by incorporating circular principles at the design stage. This includes enabling direct reuse, maintenance, repair, refurbishment, remanufacturing, and recyclability, as well as using secondary resources in production.
5. Resource Recovery: Involves extracting secondary raw materials from waste streams and closing material loops through recycling and recovery processes.

Each model can be further broken down into sub-models for specific value chain actions (Table 2) with connected Sustainable Development Goals (SDGs).

Table 2. Circular Business Models, Sub-Models, and Alignment with UN Sustainable Development Goals (SDGs).

Business Model	Sub-Model	Relevant SDGs
Circular Inputs	Build to last: Design products to have a longer lifecycle by using durable materials.	SDG 9, SDG 12, SDG 13
	Circular suppliers: Source materials and components that are either recycled, renewable, or easily repurposed.	SDG 7, SDG 9, SDG 12
Sharing Platform	Share: Create platforms that allow users to share products, increasing their utility and lifespan.	SDG 8, SDG 9, SDG 11, SDG 12
Product as a Service	Shift from product ownership to a service model where customers pay for use, not ownership.	SDG 9, SDG 12, SDG 13
	Performance as a service: Deliver service guaranteeing the product's functionality or performance.	SDG 9, SDG 12, SDG 17
Product Life Extension	Repair and Maintain: Offer repair services, extending the product lifecycle.	SDG 8, SDG 9, SDG 12
	Upgrade: Provide updates or upgrades without requiring complete replacement.	SDG 9, SDG 12
	Resell: Facilitate the resale of used products, keeping them in circulation longer.	SDG 8, SDG 12
	Remanufacture: Refurbish and remanufacture used products to like-new condition.	SDG 9, SDG 12
Resource Recovery	Recycle/Upcycle: Reprocess materials to create new products.	SDG 12, SDG 13, SDG 14, SDG 15
	Return: Establish systems for consumers to return used products for recovery or recycling.	SDG 12, SDG 13, SDG 17

Most of the outlined business models can be considered forms of sustainable circular business model innovation (SBMI) under particular conditions: if they lead to positive sustainable outcomes and if these outcomes rely on the integration of digital technologies.

It is particularly noteworthy to view product–service systems (PSSs) as key components of digital servitization, focusing on the evolution from a product-centric approach—where the emphasis is on the physical product itself—to a service-centric approach—where the primary focus is on the value delivered to the customer (Kohtamäki et al., 2019). Product–service systems (PSSs) are highlighted as business models with the potential to facilitate a societal transition towards CE and sustainability. According to Goedkoop et al. (1999), a PSS is defined as an amalgamation of three key elements: a tangible product, a service or activity with economic value, and a system or platform comprising various components and their relationships. In the work of Kristensen and Remmen (2019), it is highlighted how shifting the focus from products to services and eventually to systems broadens the scope of value creation. The findings of Kohtamäki et al. (2019) are that viewing value propositions from a system perspective offers a more comprehensive understanding of value for multiple stakeholders. Tukker (2004) further developed eight product–service system (PSS)-based business model archetypes, which vary in the degree of servitization, ranging from pure product models to pure service models. These include the following:

- Product-oriented: Focused on providing products along with additional services such as advice and consultancy.
- Use-oriented: Emphasizes product usage through leasing, renting/sharing, or pooling models.
- Result-oriented: Centres on delivering results through activity management, pay-per-service-unit, or functional result models.

4.2. Ecosystem Transformation

Hence, digitalization is reshaping the business models of solution providers, influencing their decisions on firm boundaries as they develop digital solutions that cross organizational lines within their ecosystems. This transformation extends beyond individual firms, requiring the alignment of business models across the entire ecosystem. As such, business models in the digitalization era must be examined from an ecosystem perspective (Kohtamäki et al., 2019). Circular business model innovations are inherently networked, relying on collaboration, communication, and coordination within intricate networks of interdependent yet autonomous stakeholders.

The key challenge in redesigning business ecosystems is achieving a "win–win–win" scenario (Antikainen et al., 2013), balancing the self-interests of participating actors to influence and facilitate their collective efforts in shaping a sustainable circular business model.

Figure 7 below highlights key opportunities in the maritime industry by showcasing the role of ecosystem actors in collaboration across the value chain. These opportunities focus on adopting circular practices (Chabowski et al., 2023):

- Circular Designer: Responsible for designing vessels and equipment for circular use, with a focus on upgrades, disassembly, and recycling.
- Circular Material Supplier: Supplies recycled materials to manufacturers.
- Upgrader: Enhances the efficiency and performance of existing equipment.
- Recycler: Sorts and processes various elements for recycling or reuse.
- Reverse Logistics Provider: Returns used equipment or components to manufacturers for recycling.
- IT Platform Provider: Offers data-sharing platforms to support the ecosystem.
- Researcher and Developer: Drives knowledge sharing and innovation related to circular solutions.
- Technology Provider: Provides advanced tools and technologies to optimize resource use and reduce emissions.

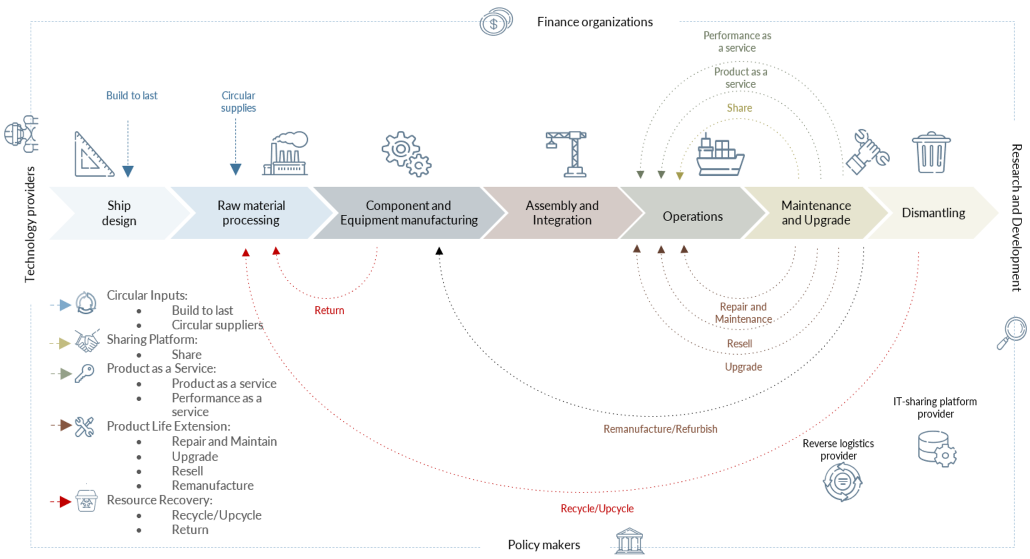

Figure 7. Sustainable Circular Business Model Innovation Ecosystem and Collaboration Across the Value System.

These actors play essential roles in enabling the circular economy within the maritime sector by facilitating product upgrades, recycling, and circular material flows.

Table 3 reflects the integration of circular economy principles throughout the maritime value chain, demonstrating how each stage adopts sustainable initiatives to move towards more circular and sustainable business models.

A typical example of circular economy (CE) practices in *operation* can be found in the activities of Wallenius Wilhelmsen. The company integrates CE principles through rental agreements and chartering services, ensuring optimal utilization of vessels. By leveraging digital tools for route optimization, Wallenius Wilhelmsen minimizes fuel consumption and emissions, aligning its operations with sustainability goals (Wallenius Wilhelmsen, 2023).

Another example of CE in action is the "Product-as-a-Service" model, exemplified by Kongsberg's "Power by the Hour" service agreement. This model transfers service planning and equipment performance responsibility from ship operators to Kongsberg, with operators paying a fixed fee based on vessel operational hours. Using onboard sensors, Kongsberg remotely monitors ship equipment in real time, ensuring optimal performance and reducing the risk of unexpected failures. This approach not only protects operators from downtime costs but also enhances operational efficiency. Kongsberg estimates that this model can cut maintenance costs by up to 25% over a 10–15-year period, providing a cost-effective and sustainable alternative to conventional maintenance strategies (Kongsberg, n.d.).

In terms of *maintenance and upgrade*, the Turku Repair Yard demonstrates CE practices by providing lifecycle services, such as ship repair, refurbishment, and repainting. These activities extend the operational lifespan of vessels, reduce the demand for new materials, and ensure that existing assets remain functional and efficient. In addition, the Turku Repair Yard maintains a strong collaboration with the Port of Naantali in ship repair and maintenance services. This partnership creates various business model opportunities, leveraging shared resources and expertise to enhance operational efficiency and sustainability (Port of Naantali, n.d.).

Table 3. Maritime Value Chain and Circular Economy Business Models with Industrial Implications.

Value Chain Stage	Example Actors	Key Products and Services	Circular Economy (CE) Initiatives
Ship Design	NSK Ship Design, SSPA, Foreship, ENG'd	Delivers comprehensive ship design, offshore engineering, and construction support services.	Build to Last—Modular design principles
Raw Material Processing	SSAB, Hydro, Outokumpu	Supplies essential raw materials, including aluminum, stainless steel, composites, syntactic foam, and concrete.	Circular Supplies—High recyclability of materials
Component and Equipment Manufacturing	Wärtsilä, Kongsberg, ABB, Promeco	Develops key maritime equipment and integrated solutions, such as power engines, propulsion systems, and advanced navigation technologies.	Modular Design, Return Waste Materials, Product-as-a-Service
Assembly and Integration	Helsinki Shipyard, Kleven, Ulstein	Builds ship hulls, assembles critical components, and completes vessels with painting, coating, and the installation of necessary equipment.	Modular Design, Product Use Extension, Repair and Remanufacture Services
Operation	Wallenius Wilhelmsen, Finnlines	Equips vessels for the transportation of goods and passengers, ensuring readiness for maritime operations.	Rental Agreements, Chartering
Maintenance and Upgrade	Turku Repair Yard, Ulstein	Offers services in ship repair, refurbishment, and conversion projects, which include replacing equipment and repainting vessels.	Lifecycle Services—Repair, refurbishment, and repainting
Dismantling	Delete, Hans Langh	Provides decommissioning services for end-of-life vessels, including dismantling, material sorting, and efficient processing for recycling or disposal.	Recycle/Upcycle, Return Services

Beyond fleet utilization and maintenance, several industry initiatives exemplify how CE is embedded in shipping operations to extend the lifespan of maritime assets, minimize waste, and promote material reuse:

- Sustainable Ship Recycling: Sea2Cradle supports shipowners in ensuring safe and environmentally responsible vessel decommissioning. Their services include hazardous material assessments, brokerage, facility audits, and recycling planning. By overseeing the entire recycling process, Sea2Cradle maximizes material recovery and aims for near-total recyclability while upholding high safety standards (Sea2Cradle, n.d.).
- Retrofit and Refurbishment: Evac offers retrofit and refurbishment solutions to upgrade vessel systems, enabling older ships to integrate modern technologies. These upgrades enhance efficiency, reduce resource consumption, and support CE by extending fleet performance while decreasing the need for new ship construction (Evac, n.d.).
- Component Remanufacturing: Wärtsilä specializes in remanufacturing worn-out engine components to restore them to full functionality. Remanufactured components maintain the same quality as new ones but come at a lower cost. This process significantly reduces maintenance expenses while minimizing environmental impact by reusing materials rather than producing new ones (Wärtsilä, n.d.).

For *dismantling*, Green Yard Kleven serves as a leading example of CE in the maritime sector. The company specializes in decommissioning end-of-life vessels, focusing on dismantling and recovering valuable materials such as steel. These materials are then recycled or upcycled, promoting resource circularity and reducing waste in the industry (Green Yard Kleven, n.d.).

In summary, circular economy (CE) principles can be categorized into three levels: micro, mezzo, and macro (Agarwala, 2023): (1) at the micro level, the focus is on reusing waste within a single company's operations; (2) the mezzo level emphasizes industrial symbiosis, where multiple companies collaborate to share resources and exchange waste materials; (3) at the macro level, CE practices extend to inter-regional networks that enable the recycling and exchange of resources across broader areas (Faut et al., 2023). These efforts primarily target economic, logistics, and industrial activities, with an emphasis on secondary ports, maritime transportation, reverse supply chains, and IT solutions (Notteboom et al., 2022). Notable examples include the Ports of Rotterdam, Amsterdam, Antwerp, Southampton, and Gävle, which have successfully implemented CE practices to enhance sustainability and operational efficiency (Razmjooei et al., 2023).

Hence, the successful implementation of circular economy (CE) principles in the maritime industry heavily relies on the collaboration and involvement of key actors throughout the value chain. Each stage from ship design to decommissioning plays a pivotal role in driving sustainability and adopting innovative business models that align with circular economy goals. To conclude, such transitioning to SCBMI poses considerable organizational challenges, as it necessitates a comprehensive redesign of the entire business model rather than just making minor operational adjustments (Widmer, 2016).

To summarize, digital advancements are steering business models away from the traditional "as-a-product" strategies and towards more dynamic "as-a-service" models, embracing agility, accessibility, and continuous engagement as the new benchmarks of success. Hence, the evolution of business models can be seen from the perspective of four archetypal business models (Korver, 2019):

- Product-Centricity and Customer-Centricity (as-a-product value delivery models). Traditional "as-a-product value" delivery models have served as the backbone of industries over decades, setting the stage for the conventional approach to value creation. In particular, *product-centric model* prioritizes the product's development, quality, and delivery as the primary value proposition. Conversely, the *customer-centric model* shifts the focus to the customer, aiming to create personalized experiences and tailor offerings that cater to individual needs and preferences.

- Resource-Centricity and Platform-Centricity (as-a-service value delivery models). However, it became clear that current frameworks were insufficient to comprehensively address both traditional and emerging business models. With the rise of contemporary trends such as the sharing economy, the Resource Economy, servitization, Uberization, and the Network Economy, the necessity to revisit and expand these paradigms became apparent. *Resource-centric models* embrace a "regenerative philosophy", focusing on maximizing utilization rather than ownership. Although resource sharing is not new, digital technologies such as the internet and mobile platforms have revolutionized this model. What sets today's *platform-centric models* apart is the digital revolution, which has dismantled the traditional barriers of geography and time. Now, digital platforms enable exchanges to occur at an unprecedented scale and speed, transforming isolated markets into interconnected ecosystems that operate with immediacy and ubiquity. As acquiring new customers becomes more challenging and expensive, organizations are shifting their focus towards customer retention. However, this transformation is proving difficult due to limited resources, varying readiness levels across departments, and competing corporate objectives that do not always align with this strategic shift (Le & Tyni, 2020). Hence, further research on *as-a-service value* models, such as SCBMI, is needed.

5. Conclusions

This theoretical analysis provides a comprehensive examination of how digital and circular innovations can fundamentally transform traditional business models and ecosystems within the maritime industry, transforming traditional production and consumption patterns. By integrating lifecycle thinking and examining the evolution of supply chains and value systems, this research highlights the critical role of digital servitization and circular business models in achieving socially beneficial, economically viable, and environmentally benign outcomes across the entire lifecycle of maritime operations. The proposed sustainable value mapping framework illustrates how digital and circular innovations reshape the business ecosystem, facilitating sustainable value creation that supports the attainment of Sustainable Development Goals (SDGs). Through this framework, the study underscores the importance of aligning value creation, delivery, and capture mechanisms within a holistic business ecosystem that prioritizes both production and consumption dimensions. Digital technologies emerge as pivotal enablers within this framework, enhancing transparency, traceability, and real-time monitoring. These capabilities optimize resource efficiency and support sustainable circular business model innovation (SCBMI) across the maritime sector. Given the industry's complexity and extensive global reach, maritime operations offer a robust context for applying and advancing these integrated approaches. This study thus provides actionable insights for stakeholders seeking to drive systemic change in line with sustainable production and consumption principles, contributing to broader community benefits, environmental stewardship, and inclusive economic growth.

Recommendations: For CE to be more widely integrated into maritime business models, the following steps are recommended:

- Policy and Regulation Alignment: Governments and maritime authorities should incentivize circular practices (e.g., tax benefits for sustainable ship recycling) and create global CE regulations to ensure industry-wide adoption.
- Adoption of Circular Business Models: Shipping companies should transition from asset-heavy ownership models to servitization models (e.g., ship leasing and maintenance-as-a-service) to optimize lifecycle utilization.

- Investment in Digital Technologies: Digitalization—through AI for predictive maintenance, blockchain for material tracking, and digital twins for optimizing ship design—should be prioritized to facilitate CE implementation.
- Industry Collaboration and Circular Supply Chains: Ports, shipyards, and logistics companies should work together to create closed-loop resource flows, ensuring ship materials, fuels, and waste are reused, recycled, or repurposed.
- Capacity Building and Awareness: Shipping stakeholders, from operators to policymakers, should receive training on CE principles and best practices, ensuring industry-wide adoption beyond isolated initiatives.

Despite its potential, integrating CE into shipping faces several challenges:

- High Initial Costs: CE technologies and practices require upfront investment. Solution: Governments and industry bodies can provide subsidies or tax incentives.
- Regulatory Inconsistencies: Different countries have varying environmental and recycling policies. Solution: Establishing international CE shipping regulations via IMO or EU frameworks can help standardize practices.
- Lack of Awareness and Resistance to Change: Many stakeholders remain focused on traditional linear business models. Solution: Conducting industry-wide training and showcasing successful CE implementations can encourage wider adoption.
- Technology Gaps and Digitalization Challenges: Many CE innovations rely on advanced technologies that are not yet universally accessible. Solution: Investing in collaborative research and piloting digital tools in key maritime hubs can accelerate adoption.

By addressing these barriers and implementing CE strategies effectively, the maritime sector can move towards a sustainable, circular business ecosystem, reducing waste, extending ship lifespans, and improving resource efficiency at a global scale.

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