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SHIP RECYCLING MARKET

REGULATORY FRAME AND PRICE FLUCTUATIONS

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This dissertation has been approved by the Three Member Examination Committee or the Assembly of the Department of Maritime Studies at the University of Piraeus, in accordance with the Regulations of the Master's Program in Maritime Administration.

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Summary

This thesis examines the economic, environmental, and regulatory facets of ship recycling practices globally using a mixed-methods approach. By combining econometric modeling with field interviews, it investigates the effects of macroeconomic factors such as freight rates, oil prices, and the demand for scrap metal on the cost and timeline of vessel demolition. Case studies from the Mediterranean and South Asia highlight just how differently ship recycling is handled around the world—particularly when it comes to protecting the environment, ensuring safe working conditions, and following regulations. This study dives into key challenges like the widespread use of Flags of Convenience and the lack of consistent enforcement. It also examines how well major international frameworks—such as the Basel Convention, the Hong Kong Convention, and the EU Ship Recycling Regulation. It also explores dismantling methods, the role of intermediaries known as cash buyers, and the environmental benefits of recovering steel. The findings make it clear that, while responsible recycling is achievable, strong financial incentives and better global policy coordination are still urgently needed. In line with the UN Sustainable Development Goals, the thesis puts forward practical recommendations to strengthen regulatory consistency, improve worker safety, and promote more sustainable management of ships at the end of their operational life.

Key Words : Ship Recycling, Maritime Regulation, Scrap Prices, Environmental Impact, Labor Safety

Περίληψη

Η παρούσα διπλωματική εργασία εξετάζει τις οικονομικές, περιβαλλοντικές και κανονιστικές πτυχές των πρακτικών ανακύκλωσης πλοίων παγκοσμίως, χρησιμοποιώντας μια προσέγγιση μεικτών μεθόδων. Συνδυάζοντας την οικονομετρική μοντελοποίηση με επιτόπιες συνεντεύξεις, διερευνά τις επιδράσεις μακροοικονομικών παραγόντων, όπως οι ναύλοι, οι τιμές του πετρελαίου και η ζήτηση για σκραπ μετάλλων, στο κόστος και το χρονοδιάγραμμα της διάλυσης των πλοίων. Μελέτες περίπτωσης από τη Μεσόγειο και τη Νότια Ασία αναδεικνύουν πόσο διαφορετικά αντιμετωπίζεται η ανακύκλωση πλοίων ανά τον κόσμο—ιδιαίτερα όσον αφορά την προστασία του περιβάλλοντος, τη διασφάλιση ασφαλών συνθηκών εργασίας και την τήρηση των κανονισμών. Αυτή η μελέτη εμβαθύνει σε βασικές προκλήσεις, όπως η ευρεία χρήση των Σημαιών Ευκαιρίας και η έλλειψη συνεπούς επιβολής. Εξετάζει επίσης πόσο καλά λειτουργούν τα μεγάλα διεθνή πλαίσια—όπως η Σύμβαση της Βασιλείας, η Σύμβαση του Χονγκ Κονγκ και ο Κανονισμός της ΕΕ για την Ανακύκλωση Πλοίων. Επίσης, διερευνά τις μεθόδους διάλυσης, τον ρόλο των μεσαζόντων γνωστών ως «cash buyers» και τα περιβαλλοντικά οφέλη από την ανάκτηση του χάλυβα. Τα ευρήματα καθιστούν σαφές ότι, ενώ η υπεύθυνη ανακύκλωση είναι εφικτή, απαιτούνται επειγόντως ισχυρά οικονομικά κίνητρα και καλύτερος παγκόσμιος συντονισμός πολιτικής. Σύμφωνα με τους Στόχους Βιώσιμης Ανάπτυξης του ΟΗΕ, η διπλωματική εργασία προτείνει πρακτικές συστάσεις για την ενίσχυση της κανονιστικής συνέπειας, τη βελτίωση της ασφάλειας των εργαζομένων και την προώθηση μιας πιο βιώσιμης διαχείρισης των πλοίων στο τέλος της επιχειρησιακής τους ζωής.

Λέξεις κλειδιά : Ανακύκλωση Πλοίων, Κανονιστικό Πλαίσιο, Τιμές Σκραπ, Περιβαλλοντικές Επιπτώσεις, Εργασιακή Ασφάλεια

Περιεχόμενα

Chapter 1 : Introduction

Purpose and Significance of the Study

Ship recycling, also known as ship demolition or shipbreaking, marks the final stage in the lifecycle of maritime vessels. It plays a pivotal role in the circular economy by enabling the recovery of valuable steel and equipment while simultaneously influencing environmental sustainability, global commodity flows, and labor dynamics. The significance of ship recycling lies not only in its economic returns but also in its potential for serious social and environmental externalities when inadequately regulated (Mikelis, 2013; Stopford, 2009).

This study aims to critically examine the economic, regulatory, and operational dimensions of ship recycling, focusing particularly on the pricing mechanisms of scrap metal, the stringency and implementation of environmental and labor standards, and the disparities among key regional players such as South Asia and the Mediterranean basin. This study adds to the expanding academic research focused on the relationship between maritime economics and the United Nations' Sustainable Development Goals (SDGs), particularly those addressing decent work, innovation in industry, and environmental sustainability (IMO, 2020).

The research adopts an interdisciplinary lens, recognizing that ship recycling exists at the intersection of shipping markets, environmental policy, and labor ethics. As the international community intensifies efforts to implement the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC), this thesis provides timely insights into compliance patterns and economic incentives (UNCTAD, 2022). A comprehensive understanding of the macroeconomic factors influencing scrap metal prices, such as global demand, shifts in the steel market, and freight trends, along with an understanding of the regulatory challenges faced by ship recycling yards, are essential for creating reasonable and well-balanced policy solutions. This kind of approach supports the long-term goals of responsible ship disposal by ensuring that recycling techniques remain economically viable, legally compliant, and environmentally sustainable.

Research Questions

The study is structured around the following key research questions:

1. **What are the primary macroeconomic factors influencing scrap pricing in the ship recycling sector?**
   This question aims to identify which indicators—such as steel demand, freight market cycles, fuel prices, and inflation—exert measurable influence on scrap values.
2. **How do regulatory frameworks affect the operational efficiency and compliance costs of ship recycling facilities?**
   This involves examining the implementation and impact of the Hong Kong Convention, Basel Convention, and EU Ship Recycling Regulation in major recycling hubs.
3. **In what ways do labor practices and environmental conditions vary across geographic regions?**
   A comparative exploration will be conducted, focusing on recycling yards in Alang (India), Chattogram (Bangladesh), Gadani (Pakistan), and Aliaga (Turkey).

Summary of Methodology

The study utilizes a **mixed-methods research design** to capture both statistical regularities and contextual complexity in ship recycling dynamics.

Quantitative Methodology:
An econometric analysis will be conducted using monthly time-series data from 2010 to 2024, including Baltic Dry Index (BDI) figures, oil prices, and scrap metal prices. Regression techniques such as Ordinary Least Squares (OLS), multicollinearity diagnostics, and time-lag analysis will be employed to model the relationship between macroeconomic variables and scrap prices (Gujarati & Porter, 2009). Data sources include Clarkson Research Services, World Bank commodity price databases, and industry reports.
Qualitative Methodology:
Semi-structured interviews will be conducted with key informants, including yard managers, labor union representatives, and environmental auditors in Turkey, India, and Bangladesh. These interviews will provide insights into ground-level challenges, such as safety practices, compliance strategies, and the socio-economic profiles of

workers. Thematic coding and content analysis will be performed based on the principles of case study research (Yin, 2017).

Thesis Structure Overview

To offer a systematic and comprehensive understanding of ship recycling, the thesis is structured into twelve chapters:

Chapter 1: Outlines the research aims, rationale, and methodological framework.
Chapter 2: Defines key terms, including 'end-of-life vessels,' 'scrap value,' and 'green recycling,' and provides a historical overview.
Chapter 3: Analyzes the financial and technical drivers that lead shipowners to retire vessels, such as age, maintenance costs, and market conditions.
Chapter 4: Maps the global distribution of ship recycling yards, identifying leading hubs and regional trends.
Chapter 5: Explores dismantling methods, including beaching, dry-dock recycling, and pier breaking, highlighting technical and environmental trade-offs.
Chapter 6: Provides a legal analysis of international and regional regulations (e.g., HKC, Basel Convention, EU-SRR), assessing enforcement mechanisms and gaps.
Chapter 7: Examines labor conditions, occupational safety, and worker health based on field observations and interviews.
Chapter 8: Investigates the economic aspects of ship recycling, including profitability, cost structures, and the influence of international trade dynamics.
Chapter 9: Presents the econometric analysis results, interpreting the statistical influence of macroeconomic variables on scrap prices.
Chapter 10: Discusses qualitative findings from field interviews, offering a nuanced understanding of stakeholder perspectives.
Chapter 11: Evaluates the environmental footprint of recycling practices, including emissions, hazardous waste management, and biodiversity impact.
Chapter 12: Synthesizes findings, discusses limitations, and offers recommendations for policymakers, industry stakeholders, and NGOs.

Chapter 2: Ship Recycling—Concepts and Definitions

2.1 Ship Recycling vs. Ship Demolition

The maritime industry utilizes several terms to describe the end-of-life treatment of vessels, with “ship recycling” and “ship demolition” being the most common. While they may appear synonymous, a critical distinction lies in their approach, scope, and underlying principles.

Ship demolition traditionally refers to the physical dismantling of a vessel primarily for the extraction of scrap steel. This process historically evolved during periods of war and economic crisis when ships were dismantled in rudimentary yards with minimal concern for environmental pollution, worker safety, or material reuse beyond basic ferrous metals (OECD, 2021). Demolition often evokes a mechanistic and unregulated process, characterized by practices such as beaching and open burning, commonly seen in South Asian yards like Chattogram (Bangladesh) and Gadani (Pakistan).

On the other hand, ship recycling is a more integrated, regulated, and environmentally conscious process, aiming not only to dismantle but also to recover, reuse, and responsibly dispose of ship components and hazardous materials (IMO, 2009). It is embedded in the principles of the circular economy, whereby resources are kept in use for as long as possible through material recovery and reuse (UNEP, 2020).

The Hong Kong International Convention (HKC) and the EU Ship Recycling Regulation (EU SRR) are key to determining the standards of modern ship recycling. These frameworks establish clear requirements aimed at ensuring the environmentally sound management of hazardous materials—such as asbestos, PCBs, and heavy metals—alongside the provision of safe working conditions and proper training for dismantling personnel. They also mandate the certification and regular auditing of Ship Recycling Facilities (SRFs) to promote compliance and transparency.

This regulatory distinction is not merely technical; it holds important consequences for both academic research and policymaking. Referring to the process as "recycling" reflects a commitment to sustainability, resource recovery, and social accountability. In contrast, the term "demolition" increasingly conveys outdated, unsafe, and environmentally harmful practices (Baumgartner & Rentschler, 2021). As such, the language used is instrumental in framing policy agendas and guiding the transition toward greener and more ethical ship recycling practices.

2.2 Lifecycle of a Ship and Factors Leading to End-of-Life Status

Every commercial vessel undergoes a well-defined lifecycle, from design and launch to operation and eventual dismantling. Understanding this lifecycle is critical to identifying the economic and operational rationale behind ship recycling decisions.

2.2.1 Phases of the Ship Lifecycle

1. **Design & Construction**
   Ships are designed based on their intended trade, regulatory standards (e.g., SOLAS, MARPOL), and expected longevity (typically 25–30 years). Material selection, fuel type, and structural layout are major cost factors at this stage.
2. **Operation & Maintenance**
   During active service, ships undergo regular dry-docking, surveys, and retrofits. Operating efficiency and compliance with environmental regulations are monitored.
3. **Performance Decline**
   As ships age, maintenance becomes costlier, and operational efficiency declines. Older vessels face difficulties meeting newer environmental regulations (e.g., IMO 2020 sulfur cap, EEXI, CII), making them less competitive.
4. **Decommissioning & Recycling**
   When the cost of continuing operations exceeds the potential revenue, or when steel scrap prices are favorable, owners opt for recycling. Some ships are sold to “cash buyers” who specialize in delivering vessels to demolition yards.

2.2.2 Factors Leading to End-of-Life

1. **Age and Structural Integrity**
   Vessels older than 20–25 years are more likely to suffer from corrosion, metal fatigue, and outdated machinery, increasing dry-docking intervals and costs (Stopford, 2009).
2. **Market Cycles and Freight Rates**
   Shipping is inherently cyclical. During downturns (e.g., the post-2008 financial crisis,

COVID-19), shipowners reduce fleet size by scrapping marginally profitable vessels (Adland & Jia, 2019).

3. **Fuel Efficiency and Environmental Regulations**
   New IMO regulations on energy efficiency and emissions impose high retrofitting costs. Older vessels without scrubbers or low-sulfur fuel compatibility are prime scrapping candidates (Clarksons Research, 2023).
4. **Scrap Steel Prices**
   Scrap prices are determined by global construction demand, iron ore prices, and local market conditions. High scrap values incentivize owners to sell ships for dismantling rather than upgrading them (BIMCO, 2022).
5. **Port Access and Insurance Costs**
   Some older ships face insurance denial or limited port access, particularly within the European Union (EU), accelerating retirement decisions.

2.3 Role of Ship Recycling in Maritime Market Dynamics

Ship recycling is not merely a waste management activity; it is a strategic tool within maritime economics, deeply intertwined with fleet management, steel supply, and global trade patterns.

2.3.1 Fleet Adjustment Mechanism

Shipowners strategically use ship recycling as a tool to manage fleet capacity and stabilize market conditions. When freight rates decline due to oversupply in the market, the removal of older, less efficient vessels through recycling can help rebalance the supply-demand equation. This alleviates downward pressure on freight rates and supports overall market recovery by reducing operational overcapacity (Stopford, 2009). Recycling decisions are typically influenced by economic viability, where vessels nearing the end of their operational life are scrapped to avoid the increasing costs associated with maintenance, insurance, and regulatory compliance.

A notable example of this dynamic occurred in 2020, during the COVID-19 pandemic. The initial disruption to global trade, followed by demand fluctuations, led to a significant drop in freight rates, particularly within the tanker and dry bulk sectors. In response, many shipowners opted for early vessel retirement as a means of mitigating losses and adjusting their fleet size to match new market realities. Such actions resulted in a noticeable increase in scrapping activity, demonstrating how recycling serves not only as an end-of-life solution but also as a short-term measure for market correction during economic downturns (UNCTAD, 2022; Mikelis, 2021).

2.3.2 Steel Recovery and Resource Economics

Ships are predominantly constructed from steel, with estimates suggesting that 85 to 90 percent of a vessel's weight is comprised of this recyclable material (Mikelis, 2013). As such, end-of-life ships represent a substantial source of secondary steel, which can be recovered and reintegrated into industrial supply chains through the process of ship recycling. This recyclable resource is particularly important for developing economies where steel demand is high but access to primary raw materials is limited or costly.

In countries such as India and Bangladesh, ship recycling plays a crucial role in meeting domestic steel needs, contributing up to 30–40 percent of national consumption depending on market cycles and annual scrapping volumes (OECD, 2021; Mikelis, 2013). The steel extracted from ships is typically re-rolled into construction-grade material, feeding local infrastructure projects and reducing the dependence on energy-intensive steel production methods such as those using blast furnaces. This process not only conserves raw materials like iron ore and coal but also results in significantly lower greenhouse gas emissions, thereby supporting broader climate and resource efficiency goals outlined in international sustainability frameworks such as the Paris Agreement and the United Nations Sustainable Development Goals (IEA, 2022; UNEP, 2020).

2.3.3 Regional Economic Impacts

Ship recycling hubs in South Asia—particularly in India, Bangladesh, and Pakistan—employ more than 100,000 workers and make a substantial contribution to their national and local economies (Mikelis, 2013; OECD, 2021). Despite their economic importance, working conditions in these yards are often informal and poorly regulated. Many workers lack formal contracts, social security, or adequate safety measures, and wages typically range between 3 and 6 USD per day, depending on the skill level and location (NGO Shipbreaking Platform, 2023). These conditions raise critical concerns about the long-term social sustainability of the industry and the vulnerability of its labor force (Baumgartner & Rentschler, 2021).

In contrast, ship recycling operations in countries like Turkey—specifically the Aliaga region—and previously in China are subject to stricter regulatory oversight. These facilities offer comparatively higher wages, enforce the use of personal protective equipment, and follow more advanced environmental protocols (European Commission, 2024; IMO, 2020). Their operations tend to incorporate more mechanized processes, such as the use of cranes, landing methods, and sealed work zones, which contribute to improved worker safety and environmental outcomes (OECD, 2021). However, these yards often face competitive disadvantages in the global market due to higher compliance and operational expenses, which limit their ability to match the low-cost structures of South Asian facilities (Baumgartner & Rentschler, 2021).

2.3.4 Regulatory Influence on Market Behavior

The gradual ratification of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) and the enforcement of the European Union Ship Recycling Regulation (EU SRR) are actively reshaping the behavior of shipowners and operators. These regulatory frameworks establish stricter environmental and safety requirements for ship recycling and promote the use of audited, certified facilities (IMO, 2023; European Commission, 2024). As a result, many shipping companies are increasingly prioritizing compliance with these standards, not only to meet legal obligations but also to align with broader Environmental, Social, and Governance (ESG) commitments.

The presence of a certified recycling yard—whether listed under the EU SRR or compliant with the HKC—can directly influence the resale value of a vessel. Ships documented with an Inventory of Hazardous Materials (IHM) and accompanied by a Ship Recycling Plan (SRP) are often valued higher, particularly in secondary markets concerned with sustainability credentials. Additionally, for shipping companies wanting to improve their environmental, social, and governance (ESG) image and reputation with stakeholders, choosing a certified yard is now a key aspect of responsible fleet management and corporate social responsibility efforts.

2.3.5 Capital Allocation and Newbuilding Trends

Ship recycling serves not only as an end-of-life solution but also as a strategic financial decision within the broader capital allocation process of shipping companies. By dismantling and scrapping older vessels, shipowners are able to free up capital that would otherwise remain tied to aging, inefficient assets with declining operational and resale value. This released capital can then be reinvested in newer, more technologically advanced vessels that are better aligned with regulatory trends and environmental performance expectations (Stopford, 2009).

In many cases, the decision to recycle is closely linked with the timing of new newbuilding orders. This is especially clear when ship owners want to improve their fleets with ships that use dual-fuel engines or other types of engines—like liquefied natural gas (LNG), methanol, or ammonia—because they expect tougher rules on emissions and goals for reducing carbon set by the International Maritime Organization (IMO, 2021; Clarksons Research, 2023). Recycling, therefore, supports fleet renewal and facilitates the transition toward a lower-carbon, innovation-driven maritime sector.

Chapter 3: Drivers of Ship Demolition

The decision to retire a vessel and send it for demolition is rarely taken lightly. It reflects a confluence of economic calculations, technical evaluations, regulatory requirements, and, in some cases, responses to external shocks. Ship demolition is a strategic tool in fleet management, and understanding the motivations behind it is crucial for interpreting the supply-side dynamics of global shipping.

3.1 Economic Drivers

3.1.1 Freight Rates and Market Cycles

The inherently cyclical nature of maritime markets makes freight rates one of the most influential factors affecting demolition activity. When earnings from vessel operations fall below the threshold needed to cover daily operating and capital costs, shipowners are often compelled to remove older, less efficient vessels from their fleets. This is particularly common during market downturns, when reduced cargo demand and oversupply lead to sustained low freight rates. In such conditions, demolition becomes a financially rational strategy to mitigate losses and rebalance fleet capacity (Stopford, 2009).

Historical data reveal a strong correlation between declining freight rates and increased scrapping volumes. Following the 2008 global financial crisis, for example, the dry bulk and container segments experienced a dramatic collapse in freight markets, prompting widespread vessel retirement. A similar pattern emerged in early 2020 during the COVID-19 pandemic. Although the initial shock temporarily boosted tanker earnings due to floating storage demand, rates quickly declined thereafter, prompting the demolition of older Very Large Crude Carriers (VLCCs) and Suezmax tankers. The crisis also severely affected the cruise industry, which saw a significant decline in global tourism and prolonged port closures. As a result, nearly 40 cruise ships—many of them aging and non-compliant with emerging health and safety protocols—were sent for recycling between 2020 and 2021, marking one of the most notable contractions in the passenger vessel segment in recent history (UNCTAD, 2022; Mikelis, 2021).

3.1.2 Bunker Costs and Fuel Efficiency

Fuel costs, especially marine gas oil (MGO) and very low sulfur fuel oil (VLSFO), constitute up to 60% of a ship's operating expenses (Clarksons Research, 2023). Older ships generally have less fuel-efficient engines, making them increasingly uneconomical during periods of high bunker prices.

For instance, the enforcement of the IMO 2020 sulfur cap, which banned high-sulfur fuel oil (HSFO) without scrubbers, prompted many owners to scrap vessels rather than retrofit them, especially in the small tanker and bulk sectors (BIMCO, 2020).

3.1.3 Obsolescence and Technological Lag

Beyond earnings and costs, ships may become functionally obsolete. Technological evolution, such as the shift toward dual-fuel engines, LNG propulsion, and digital monitoring systems, makes older tonnage less attractive for charterers and financiers.

Obsolete vessels are often penalized with higher insurance premiums, limited port access (e.g., EU ports under the EU SRR), and longer turnaround times. As shipowners and operators increasingly factor in ESG performance, older ships become liabilities rather than assets (Baumgartner & Rentschler, 2021).

3.2 Regulatory and Technical Pressures

3.2.1 Environmental Regulations: GHG, EEXI, and CII

The International Maritime Organization (IMO) has introduced a series of greenhouse gas (GHG) regulations aimed at aligning maritime transport with global decarbonization targets. Among the most significant instruments are the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII). The EEXI, which came into force in 2023, establishes minimum energy efficiency requirements for existing ships, thereby compelling operators to enhance technical performance through measures such as engine modifications or hull improvements. In parallel, the CII introduces an annual performance rating system that assesses vessels based on their carbon dioxide emissions per unit of transport work, using a scale from A to E.

Ships that consistently receive poor ratings or fail to meet EEXI standards are at risk of being excluded from certain markets or losing charter opportunities. To avoid these outcomes, owners must invest in often costly retrofits, including engine power limitations, propeller upgrades, or the installation of energy-saving devices. For older vessels, however, the economics of such investments are frequently unfavorable. Often, the anticipated returns do not justify the retrofit costs, particularly for ships nearing the end of their operational life. As a result, the cost-benefit analysis frequently leads to early demolition, making regulatory compliance a significant driver of ship recycling decisions in the current policy environment (IMO, 2021; Clarksons Research, 2023).

3.2.2 SOLAS and Safety-Related Standards

Technical regulations under SOLAS (Safety of Life at Sea) also influence demolition decisions. As vessels age, compliance with safety protocols (lifesaving appliances, structural integrity, firefighting systems) becomes harder and more expensive.

Furthermore, certain flag states impose restrictions on ship ages, such as banning vessels over 25 years from registry or insurance coverage, nudging owners toward demolition once regulatory renewal becomes too burdensome (OECD, 2021).

3.3 Crisis-Induced Scrapping Behavior

3.3.1 The Global Financial Crisis (2008–2010)

The collapse of Lehman Brothers in 2008 and the subsequent global financial crisis had a profound impact on international trade and shipping markets. As the global economy contracted, demand for seaborne goods declined sharply, leading to a dramatic fall in charter rates across virtually all vessel segments. The resulting oversupply of tonnage left many ships idle, while asset values plummeted. Confronted with these unfavorable market conditions, shipowners were compelled to reduce fleet size by scrapping older and less efficient vessels, both as a means of cutting losses and rebalancing capacity (Stopford, 2009; UNCTAD, 2010).

In 2009 alone, more than 40 million deadweight tons (DWT) of shipping capacity were sent for demolition—an all-time record at the time—highlighting the scale of the industry's response to the crisis (UNCTAD, 2010). Bulk carriers and aging containerships were especially affected, given their lower operational efficiency and weaker earnings potential. This period serves as a clear example of how moments of economic disruption can accelerate the retirement of marginal vessels, thereby facilitating a faster correction in fleet oversupply. In doing so, crisis-driven demolition indirectly contributes to the foundations for future market recovery (Baumgartner & Rentschler, 2021; Clarksons Research, 2023).

3.3.2 COVID-19 Pandemic (2020–2021)

The COVID-19 pandemic introduced substantial uncertainty into the global shipping industry, disrupting trade flows, complicating crew changes, and limiting port access due to evolving health protocols and restrictions. While certain market segments—most notably container shipping—experienced a swift recovery driven by increased demand for consumer goods, other sectors faced prolonged downturns. Particularly, the collapse of international tourism and mounting regulatory uncertainty severely affected the cruise industry. In response, several cruise lines opted to retire entire classes of vessels, many of which were older, high-emission ships that would have required significant investment to comply with emerging health and environmental standards.

Similarly, small product tankers and handysize bulk carriers that lacked scrubbers or failed to meet the Energy Efficiency Existing Ship Index (EEXI) requirements became prime candidates for scrapping. These vessels were no longer economically viable in a context of low spot rates and rising fuel and compliance costs. The pandemic thus underscored how external, non-market shocks—such as global health emergencies—can act as catalysts for accelerated fleet renewal. In such cases, the decision to scrap is driven not only by economic metrics but also by the need to adapt to rapidly changing regulatory and operational landscapes (Mikelis, 2021; Clarksons Research, 2023; UNCTAD, 2022).

Chapter 4: Geographic Evolution and Current Global Landscape

Ship recycling has undergone a significant geographic transformation over the past century. From a primarily Western, industrialized operation in the mid-20th century, it has shifted decisively toward developing economies in South Asia and parts of the Eastern Mediterranean. This transformation reflects broader trends in global economic restructuring, labor cost optimization, environmental policy displacement, and the pursuit of resource recovery in less regulated environments.

4.1 Historical Shift from Europe/USA to South Asia

During the mid-20th century, shipbreaking activities were primarily concentrated in Western industrialized nations, including the United Kingdom, Germany, the Netherlands, and the United States. These operations were typically located near established ports and shipbuilding centers, and dismantling was carried out in dry docks or slipways using trained labor. Importantly, these early recycling activities were subject to the occupational safety and environmental regulations prevalent in developed countries at the time (OECD, 2021).

However, a dramatic geographic shift began to take place in the 1970s and 1980s, leading to the relocation of ship recycling operations to the Global South, particularly to South Asia. This transition was driven by a confluence of economic and structural factors. Rising labor costs and stricter environmental compliance requirements in Europe and North America made ship recycling less profitable in those regions. At the same time, a growing supply of decommissioned naval vessels—following the Vietnam War and later the Cold War—created new opportunities for dismantling. Countries such as India and Bangladesh, characterized by abundant low-cost labor, limited regulatory enforcement, and a high domestic demand for recovered steel, quickly became attractive destinations for these activities (Baumgartner & Rentschler, 2021; Mikelis, 2013).

This shift is a clear example of “regulatory outsourcing,” whereby environmentally hazardous or labor-intensive processes are relocated to jurisdictions with weaker oversight and enforcement capacity. The result has been the emergence of South Asia as the dominant global hub for ship recycling—a position it continues to hold today, despite persistent concerns over worker safety, environmental degradation, and uneven regulatory compliance (UNCTAD, 2022; NGO Shipbreaking Platform, 2023).

4.2 Key Locations in the Current Global Landscape

4.2.1 India—Alang, Gujarat

India's Alang yard, located in the state of Gujarat, is recognized as the largest ship recycling facility in the world in terms of both capacity and throughput. Since its establishment in the early 1980s, Alang has expanded to occupy more than 10 kilometers of coastline along the Arabian Sea and comprises over 100 operational plots dedicated to ship dismantling. In recent years, the facility has consistently accounted for approximately 30 to 40 percent of global ship recycling activity by volume, making it a critical node in the international shipbreaking landscape (Mikelis, 2013; OECD, 2021).

The predominant dismantling method used at Alang is beaching, whereby ships are deliberately run aground on tidal mudflats at high tide and then manually cut apart as the tide recedes. While this method is cost-effective and allows for the handling of large vessels, it has been criticized for its environmental and safety risks. Nonetheless, Alang has made notable progress in aligning with international standards. Several yards have obtained certification under the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC), reflecting efforts to improve infrastructure, hazardous waste management, and worker safety (IMO, 2023).

Despite these advancements, the working conditions remain challenging. The yard employs over 20,000 workers, many of whom are seasonal or migrant laborers originating from economically disadvantaged regions such as Bihar and Uttar Pradesh. These workers often operate in high-risk environments with limited protective equipment and inconsistent access to healthcare, although recent reforms have led to gradual improvements in occupational safety and regulatory oversight (Baumgartner & Rentschler, 2021; NGO Shipbreaking Platform, 2023).

4.2.2 Bangladesh—Chattogram (Chittagong)

Bangladesh emerged as a significant hub for global ship recycling in the 1990s, particularly following the Gulf War, which triggered a wave of tanker scrapping. The country's primary shipbreaking center, located in Chattogram (formerly Chittagong), has since become one of the most active dismantling zones worldwide. Today, Chattogram is responsible for approximately 20 to 25 percent of global ship recycling volumes, relying predominantly on the beaching method, where vessels are driven onto tidal flats for manual disassembly (UNCTAD, 2022).

The industry plays a vital role in the national economy, particularly in the construction and manufacturing sectors. It is estimated that ship recycling in Bangladesh supplies up to 60 percent of the country's steel demand, making it a critical component of domestic infrastructure development and industrial growth (Mikelis, 2013; OECD, 2021). However, serious concerns about labor conditions and environmental practices temper this economic significance. Chattogram's yards are frequently cited as among the most hazardous in the world, with persistent reports of workplace fatalities, chronic asbestos exposure, and the illegal employment of underage laborers. Despite international pressure and intermittent policy interventions, enforcement remains inconsistent, raising substantial concerns about worker welfare and the overall sustainability of the industry (NGO Shipbreaking Platform, 2023; Baumgartner & Rentschler, 2021).

4.2.3 Pakistan—Gadani

Situated along the Arabian Sea coast near Karachi, Pakistan's Gadani shipbreaking yard was once the largest in the world, peaking in prominence during the 1980s. At its height, Gadani was a major global hub for ship dismantling, attracting large volumes of decommissioned vessels due to its low operating expenses and expansive beaching areas. Although the facility has since experienced a decline in activity, it continues to play a notable role in the global ship recycling market, currently accounting for an estimated 10 to 15 percent of total scrapping output (Mikelis, 2013; OECD, 2021).

However, compared to other leading facilities in countries such as India and Turkey, the regulatory framework governing Gadani is considerably weaker. Safety protocols and labor standards remain poorly enforced, leading to frequent and often fatal accidents. A particularly tragic example occurred in 2016, when an oil tanker explosion at the site claimed the lives of more than 25 workers and injured dozens more, underscoring the severe risks associated with inadequate safety oversight (Baumgartner & Rentschler, 2021). In addition to human safety concerns, the yard also suffers from limited infrastructure and poor environmental controls. Oil spills, heavy metal contamination, and paint runoff into coastal waters are ongoing issues that contribute to significant ecological degradation. Despite its historical importance, Gadani's continued relevance in the global ship recycling sector remains overshadowed by persistent challenges related to safety, environmental harm, and regulatory enforcement (NGO Shipbreaking Platform, 2023; UNCTAD, 2022).

4.2.4 Turkey—Aliaga

Aliaga, located on the Aegean coast of Turkey, represents a distinctive case within the global ship recycling sector due to its adoption of semi-industrialized dismantling techniques. Unlike traditional beaching practices seen in South Asia, Aliaga employs a method where ships are pulled ashore using chains onto sloped platforms rather than dry docks. This hybrid approach, while not fully mechanized, offers a more controlled dismantling environment and aligns more closely with European Union standards for environmental protection and labor safety (OECD, 2021).

Aliaga currently accounts for approximately 5 percent of global ship recycling activity and is particularly significant for processing EU-flagged vessels. These ships are subject to the European Union Ship Recycling Regulation (EU SRR), which mandates that scrapping occur only in approved facilities listed on the official EU SRR registry (European Commission, 2024). The dismantling process in Aliaga typically takes place through landing or quay-side methods, thereby avoiding many of the ecological harms associated with open beaching, such as tidal contamination and sediment pollution.

Importantly, Aliaga is one of the few ship recycling hubs worldwide that consistently meets both the Hong Kong Convention (HKC) and EU SRR requirements. This adherence to regulations, along with better facilities and stronger protections for workers, has made Aliaga a popular choice for shipowners who want to ensure their old ships are handled in a way that meets environmental, social, and governance (ESG) goals and follows global best practices.

4.2.5 China—Historical Role

Until approximately 2018, China was considered a major actor in the global ship recycling industry. State-owned enterprises, operating within comparatively stricter regulatory frameworks, primarily conducted the country's dismantling operations. These facilities commonly utilized dry docks or piers—rather than environmentally sensitive beaching methods—and adhered to higher labor and safety standards relative to their South Asian counterparts (OECD, 2021).

However, in 2019, the Chinese government implemented a comprehensive ban on the import of foreign end-of-life vessels, citing environmental concerns and a broader national agenda to reduce industrial pollution and enhance ecological protections (IMO, 2020). This policy decision caused a major change in the global recycling landscape. China's withdrawal from the international scrapping market caused shipbreaking activities to move to established centers in South Asia—especially in India, Bangladesh, and Pakistan—strengthening the global recycling industry in areas with fewer regulations and cheaper labor costs.

4.2.6 Denmark—Grenaa (Nordic Model)

Although modest in scale, Grenaa, Denmark, serves as a representative example of the Nordic approach to environmentally responsible ship recycling. Operated by specialized firms such as Modern American Recycling Services (M.A.R.S.), the facility employs advanced dismantling techniques, including the use of dry docks and closed-loop waste management systems that prevent the release of hazardous materials into the surrounding environment. These practices are consistent with the highest environmental and safety standards and are designed to ensure full regulatory compliance throughout the dismantling process (OECD, 2021).

Grenaa primarily handles naval vessels and ships owned by European Union institutions or member states, operating under close EU oversight. While its operations are not cost-competitive with the larger facilities in South Asia or Turkey—largely due to higher labor costs and strict environmental requirements—the site plays an important role in setting the benchmark for what constitutes best practice in sustainable ship recycling. Its model demonstrates the technical feasibility of conducting shipbreaking in a way that is both socially responsible and ecologically sound, reinforcing the regulatory ambitions of the EU Ship Recycling Regulation (European Commission, 2024; NGO Shipbreaking Platform, 2023).

4.3 Comparative Insights from Case Studies

Location	Method	HKC/EU Compliance	Cost Level	Labor Safety	Market Share
Alang (India)	Beaching	Partial	Medium	Improving	High
Chattogram	Beaching	Low	Low	Poor	High
Gadani	Beaching	Low	Very Low	Very Poor	Moderate
Aliaga	Quay/landing	High	High	High	Medium
Grenaa	Dry dock	Very High	Very High	Very High	Very Low

Table 4.1 Comparative Characteristics of Major Ship Recycling Locations by Method, Compliance, Cost, Labor Safety, and Market Share , Source by combination of data

Table 4.1 gives a comparison of important global ship recycling places based on how they take apart ships, how well they follow international rules (like the Hong Kong Convention and EU Ship Recycling Regulation), their costs, safety for workers, and their share of the market.

The data underscores significant disparities between major South Asian yards and those located in Turkey and Northern Europe. Specifically, beaching yards such as Alang, Chattogram, and Gadani dominate the global market in terms of volume, primarily due to their low operating expenses and capacity to accommodate very large vessels (Mikelis, 2013; UNCTAD, 2022). However, these advantages come at the expense of labor safety and environmental oversight, with Chattogram and Gadani exhibiting persistently low compliance with international safety and waste management standards (OECD, 2021; NGO Shipbreaking Platform, 2023).

Conversely, Aliaga in Turkey and Grenaa in Denmark exemplify higher regulatory adherence and worker protection, utilizing quay-side and dry dock dismantling techniques, respectively. These facilities meet the requirements of both the Hong Kong Convention and the EU Ship Recycling Regulation, offering mechanized operations, trained personnel, and improved hazardous material control (European Commission, 2024; IMO, 2023). However, the associated costs are substantially higher, which limits their competitiveness in price-driven markets.

While the South Asian model remains dominant due to cost advantages, its sustainability is increasingly being questioned. The higher costs of running operations and following rules in Aliaga and Grenaa make it hard for businesses to adopt eco-friendly practices, especially in a market that is divided and competitive, where making money often matters more than following regulations (Baumgartner & Rentschler, 2021).

Chapter 5: Methods of Ship Dismantling

Ship dismantling methods vary considerably across geographic and economic contexts. The chosen method is shaped by the facility's infrastructure, the vessel's size and type, the regulatory environment, labor costs, and the intended balance between operational efficiency and environmental safety. This chapter provides an overview of the four primary dismantling techniques: beaching, slipway, dry-docking, and alongside dismantling, offering a comparative analysis supported by operational and ecological considerations.

5.1 Overview of Ship Dismantling Methods

5.1.1 Beaching

Beaching remains the most widely used method of ship dismantling in South Asia, particularly in India (Alang), Bangladesh (Chattogram), and Pakistan (Gadani). In this method, vessels are directed onto tidal mudflats during high tide, either under their propulsion or with the assistance of tugboats. Once the vessel is grounded, dismantling typically begins at the bow and progresses towards the stern as the tide recedes.

This approach offers several economic and logistical advantages. It requires minimal infrastructure investment, making it accessible to facilities in developing countries. Moreover, the open tidal flat environment can accommodate enormous ships, including Very Large Crude Carriers (VLCCs) and capesize bulkers, without the constraints of dry docks or slipways. The turnaround time for dismantling is also relatively short, enabling a high throughput of vessels.

However, the beaching method has been subject to widespread criticism due to its environmental and safety shortcomings. The absence of impermeable surfaces and containment systems often leads to significant pollution from oil residues, heavy metals, and other toxic substances. Additionally, the unstable ground conditions and reliance on manual cutting techniques contribute to a hazardous working environment. Protective equipment is often insufficient or entirely lacking, and hazardous waste such as asbestos and polychlorinated biphenyls (PCBs) is frequently mismanaged or left exposed to the natural environment (Baumgartner and Rentschler, 2021).

Aerial imagery of shipbreaking yards in Alang or Chattogram typically reveals numerous beached vessels being dismantled in open tidal zones, with workers engaged in manual cutting operations under unsafe and unregulated conditions.

5.1.2 Slipway Dismantling

Using winches and heavy-duty cables, slipway dismantling pulls decommissioned vessels onto an inclined concrete or steel ramp. This approach facilitates the gradual disassembly of ships in a more structured and controlled environment compared to beaching. It is commonly employed in countries such as Turkey and, until recently, in parts of China, particularly in facilities that aim to balance operational efficiency with improved environmental management (Mikelis, 2013; European Commission, 2024).

One of the primary benefits of the slipway method is its enhanced ability to contain waste and manage runoff. The ramp's engineered slope allows for partial control of pollutants and hazardous substances that may otherwise seep into the marine ecosystem. Furthermore, the working surface is more stable than the tidal mudflats used in beaching, reducing the likelihood of accidents due to unstable footing or shifting ship structures. Mechanized equipment, such as cranes and forklifts, can be more safely deployed in this setting, thereby contributing to improved occupational safety for dismantling crews (Baumgartner & Rentschler, 2021; OECD, 2021).

Despite these advantages, slipway dismantling also presents several challenges. The initial infrastructure investment is significantly higher than that required for beaching yards, and regular maintenance of the slipway is essential to ensure operational integrity and safety. Additionally, the method has limitations in terms of capacity; huge vessels, such as ultra-large container ships or VLCCs, may exceed the structural or spatial limits of slipway facilities and are therefore less likely to be dismantled using this approach (IMO, 2023).

Illustrative diagrams of slipway operations often depict sectional removal of ship components with adjacent containment trenches for collecting oils and other waste residues. Such visual representations underscore the method's potential for environmental control and worker safety, particularly when supported by regulatory oversight and technical capacity (NGO Shipbreaking Platform, 2023).

5.1.3 Dry-Docking

Dry-docking dismantling involves transferring the vessel into a watertight dock that is subsequently sealed and drained, thereby exposing the entire hull and facilitating safe and controlled disassembly. This method is primarily employed in European Union-approved facilities and was historically more common in China, particularly prior to its 2019 ban on the import of foreign-flagged end-of-life ships (IMO, 2020; European Commission, 2024).

One of the most significant advantages of dry-docking lies in the degree of environmental and operational control it offers. The enclosed environment ensures maximum containment of pollutants, allowing for more effective management of hazardous substances such as asbestos, polychlorinated biphenyls (PCBs), and residual oils. This method is particularly well-suited to ship recycling operations in or near environmentally sensitive areas, where strict regulatory compliance is required. Moreover, the dry-dock setting enables the efficient use of cranes, forklifts, and other heavy machinery, thereby enhancing both safety and productivity (OECD, 2021; Baumgartner & Rentschler, 2021).

Despite its operational advantages, dry-docking is characterized by considerable economic limitations. The capital investment required to construct and maintain a dry-dock facility is substantial, and operating expenses—particularly related to water management, safety systems, and mechanical handling—are significantly higher than those of open-air or beaching methods. Furthermore, the physical dimensions of most dry docks restrict their use to mid-sized or smaller vessels, making the method impractical for large container ships or huge crude carriers (VLCCs). As a result, dry-docking is rarely chosen for low-value vessels where the costs of dismantling may exceed potential scrap returns (OECD, 2021; Mikelis, 2013).

Technical diagrams of dry-dock recycling facilities typically illustrate clearly demarcated zones for hazardous material handling, component staging, and liquid waste collection systems. These images underscore the precision and containment capabilities of this dismantling method, in contrast to the unstructured and pollutive nature of beaching practices.

5.1.4 Alongside Dismantling (Quayside)

Alongside dismantling, also referred to as quay-side dismantling, is a method in which a ship is taken apart while moored alongside a quay or pier. This technique is primarily employed in highly regulated environments, such as in Turkey's Aliaga and Denmark's Grenaa, and is typically reserved for smaller vessels, government-owned ships, or naval units. The process involves the sequential removal of ship components from the deck downward using cranes, scaffolding, and other mechanized systems, while ensuring the containment and collection of hazardous materials in a controlled setting.

This method offers several operational and environmental benefits. It provides excellent access for machinery and personnel, which facilitates more efficient and safer dismantling operations. The proximity to infrastructure enables the use of high-capacity cranes and containerized waste handling systems, which significantly reduces the likelihood of pollutants entering the marine environment. Consequently, alongside dismantling is generally compliant with international regulatory standards such as the EU Ship Recycling Regulation (EU SRR) and the Hong Kong Convention (HKC), making it a preferred approach for shipowners seeking to meet environmental, social, and governance (ESG) criteria (European Commission, 2024; IMO, 2023).

Despite these advantages, quay-side dismantling does have limitations. It is usually constrained to vessels of modest size, or to ships that have already undergone partial dismantling elsewhere, due to space and structural restrictions along commercial port quays. Moreover, this method requires highly developed port infrastructure, including heavy-duty berths, containment systems, and nearby hazardous waste treatment facilities. In busy ports, dockside congestion can also reduce the availability of quay space and affect the timeliness and productivity of recycling operations (OECD, 2021; Baumgartner & Rentschler, 2021).

Photographs of this dismantling technique typically depict cranes removing large hull sections from vessels at berth, with dedicated areas nearby for component staging and waste sorting. These visual representations emphasize the method's structured and regulatory-compliant nature, in contrast to more informal dismantling environments.

5.2 Comparative Analysis of Dismantling Methods

Method	Cost	Environmental Risk	Worker Safety	Infrastructure Needs	Vessel Size Limit	Regulatory Compliance Potential
Beaching	Low	High	Low	Minimal	Very Large	Low–Medium (if upgraded)
Slipway	Medium	Medium	Medium	Moderate	Large	Medium
Dry Docking	Very High	Low	High	High	Medium	High
Alongside/Quayside	High	Low	High	Moderate–High	Small–Medium	High

Table 5.1: Comparative Assessment of Ship Dismantling Methods by Cost, Environmental, and Operational Criteria , Source combination of data

Table 5.1 shows a comparison of the four main ways to dismantle ships—beaching, slipway, dry docking, and alongside/quay-side dismantling—based on important operational and environmental factors. The analysis highlights significant variation in cost structures, risk exposure, infrastructure demands, vessel handling capacity, and potential for regulatory compliance. Among these methods, beaching remains the most widely applied due to its low cost and capacity to accommodate enormous vessels. However, this method is also associated with the highest environmental risks and the lowest levels of worker safety due to minimal containment systems and limited mechanization (Baumgartner & Rentschler, 2021; Mikelis, 2013).

In contrast, dry-docking and alongside dismantling—commonly implemented in countries like Turkey and Denmark—entail significantly higher costs but offer substantial benefits in terms of pollution control, labor protection, and compliance with international conventions such as the Hong Kong Convention and the EU Ship

Recycling Regulation (OECD, 2021; European Commission, 2024). Slipway dismantling represents an intermediate option, offering a balance between environmental control and cost efficiency. However, its capacity limitations and need for moderate infrastructure may restrict its broader application. Overall, the choice of dismantling method involves strategic trade-offs between financial feasibility and environmental and regulatory accountability, emphasizing that there must be policy interventions to incentivize safer and more sustainable recycling practices (IMO, 2023; NGO Shipbreaking Platform, 2023).

5.3 Environmental and Operational Considerations

5.3.1 Hazardous Waste Management

Different dismantling methods vary in their ability to handle asbestos, PCBs, oils, and heavy metals. Dry docking and quay-side methods offer sealed environments for proper removal and disposal, while beaching often results in uncontained leakage into coastal ecosystems (IMO, 2020).

5.3.2. Oil and Chemical Runoff

One of the most persistent environmental concerns associated with ship recycling operations is the discharge and mishandling of pollutants such as oil residues, bilge water, and hydraulic fluids. These substances are routinely found in the tanks, pipes, and machinery of end-of-life vessels, and if not properly removed and treated, can cause severe contamination to coastal ecosystems. This issue is particularly acute in beaching yards, where the lack of engineered containment systems means that oily effluents often mix directly with seawater during tidal cycles. As a result, intertidal zones—including mudflats, mangroves, and nearshore fisheries—are frequently exposed to hydrocarbons and heavy metals, which degrade biodiversity and threaten the livelihoods of local fishing communities (Baumgartner & Rentschler, 2021; NGO Shipbreaking Platform, 2023).

In contrast, facilities that employ dry-docking methods typically operate under stricter environmental controls. These yards are equipped with containment pits, sealed drainage channels, and oil-water separation units that significantly reduce the risk of marine pollution. By isolating the hull within a dry basin, operators can collect and process hazardous fluids before dismantling begins, thereby limiting the release of pollutants into the surrounding environment. Such infrastructure also allows for compliance with international conventions, including the Hong Kong Convention and the EU Ship Recycling Regulation, both of which require documented procedures for the safe handling and disposal of oil and chemical waste (IMO, 2023; European Commission, 2024). The comparison between these two methods highlights the extent to which infrastructure and regulatory oversight influence environmental outcomes in ship recycling practices.

5.3.3 Worker Health and Safety

Occupational health and safety conditions vary significantly depending on the dismantling method employed. In beaching yards, the dismantling process is predominantly manual, with workers frequently using gas torches to cut steel structures without the use of adequate personal protective equipment. This exposes them to a range of physical hazards, including falling steel plates, shifting hull sections, and prolonged inhalation of toxic fumes released during cutting operations. The absence of safety scaffolding, gas-free certification procedures, and emergency response infrastructure further exacerbates the risk profile of such environments (NGO Shipbreaking Platform, 2023).

In contrast, dry-docking and quay-side dismantling facilities are generally characterized by higher levels of mechanization and adherence to safety protocols. The use of cranes, forklifts, and purpose-built scaffolding not only reduces the physical strain on workers but also minimizes their direct exposure to hazardous materials. Moreover, workers in these settings are more likely to receive formal training and undergo periodic health checks, while the work environment itself is governed by stricter occupational safety standards and oversight. These conditions contribute to significantly lower accident rates and improved long-term health outcomes for dismantling personnel (NGO Shipbreaking Platform, 2023).

5.3.4 Compliance with Global Conventions

Among the various ship dismantling methods currently in practice, only dry-dock and alongside (quay-side) dismantling consistently meet the environmental and safety standards established by the major international regulatory frameworks. These include the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC), the European Union Ship Recycling Regulation (EU SRR), and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The structured and enclosed nature of these dismantling methods facilitates effective containment of hazardous materials and allows for greater oversight of dismantling operations. Additionally, they offer the necessary setup for properly sorting waste, keeping records, and safely removing materials, which are all essential for meeting international rules (IMO, 2023; European Commission, 2024; UNEP, 2020).

In contrast, open and unregulated methods such as beaching often fall short of these requirements due to their lack of waste containment systems, limited worker protections, and high risk of environmental contamination. As the world pays more attention to sustainable shipping practices, it's becoming more important for a dismantling method to meet these rules, which is crucial for both enforcing policies and making responsible choices in the shipping industry.

5.4 Strategic Selection of Dismantling Method

From the perspective of shipowners, the decision regarding the dismantling method and location is shaped by a complex interplay of financial, regulatory, and reputational considerations. Financial returns remain a primary driver, with owners weighing the scrap value of recoverable steel against the associated costs of dismantling. In regions where labor and operational expenses are lower—such as South Asia—beaching continues to offer the most competitive returns. However, these economic benefits are increasingly being tempered by rising regulatory scrutiny and environmental accountability, particularly for vessels flying EU flags or calling at EU ports (Baumgartner & Rentschler, 2021; European Commission, 2024).

In addition to economic incentives, shipowners must now consider regulatory compliance and corporate social responsibility obligations, especially in light of environmental, social, and governance (ESG) frameworks. Reputational risk has emerged as a critical factor, with stakeholders—including charterers, financiers, and insurers—demanding greater transparency in end-of-life ship management. As a result, many shipowners who want to meet green certification standards, like the Green Passport or the Inventory of Hazardous Materials (IHM), are choosing recycling yards in places like Aliaga (Turkey), Grenaa (Denmark), or certified facilities in India that follow the rules of the Hong Kong Convention (IMO, 2023; NGO Shipbreaking Platform, 2023). These locations, although more costly, offer assurance of adherence to international standards and help mitigate reputational liabilities through documented best practices.

Chapter 6: Regulatory Frameworks and Standards

Ship recycling sits at the intersection of environmental protection, labor rights, and global trade regulation. Given its transboundary nature, the sector is governed by a complex matrix of international, regional, and national instruments. However, implementation remains inconsistent, often undermined by Flags of Convenience (FOCs) and limited enforcement in key dismantling states. This chapter reviews the major regulatory frameworks, their effectiveness, and the challenges posed by circumvention and non-compliance.

6.1. Basel Convention and the Ban Amendment

Adopted in 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was the first comprehensive global treaty to address the international trade of hazardous materials, including end-of-life vessels destined for dismantling. The Convention classifies any ship containing hazardous substances—such as asbestos, polychlorinated biphenyls (PCBs), or oil sludge—as "hazardous waste" if it is intended for recycling. Accordingly, its transboundary movement from one country to another is subject to strict controls (UNEP, 2020).

A key provision of the Convention is the requirement for **prior informed consent (PIC).** This means that if a hazardous vessel is being transferred across national borders, particularly from a country within the Organisation for Economic Co-operation and Development (OECD) to a non-OECD country, the exporting nation must notify and obtain consent from the receiving country before the transaction takes place. This requirement is intended to protect developing nations from becoming unregulated dumping grounds for toxic maritime waste. The **Ban Amendment, which was added in 1995 and started being enforced in 2019, broadened the rules of the Convention by completely banning the export of hazardous waste from OECD to non-OECD countries, regardless of prior informed consent (PIC).**

Despite its legal strength, the practical implementation of the Basel Convention remains limited in the context of ship recycling. A major challenge arises from the practice of **re-flagging**, whereby ships are registered under flags of convenience and sold to cash buyers while still in operational condition. This tactic allows shipowners to bypass the legal classification of the vessel as “waste,” thereby avoiding the obligations set forth in the Convention. Additionally, many ship-owning states are either not signatories to the Ban Amendment or apply a narrow interpretation of its terms, further undermining enforcement efforts (Baumgartner & Rentschler, 2021). These systemic loopholes continue to complicate global efforts to regulate the environmentally sound and equitable dismantling of ships.

6.2 Hong Kong Convention (HKC, 2009)

Seeing that the Basel Convention has limits in managing how old ships are treated, especially because it's unclear when a ship is considered "waste," the International Maritime Organization (IMO) created a more specific set of rules called the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC). Adopted in 2009, the HKC aims to establish a global standard for ship recycling that takes into account the entire lifecycle of a vessel, from design and operation to final dismantling. The Convention applies to ships exceeding 500 gross tonnage (GT) engaged in international trade and outlines several key obligations. These include the requirement for vessels to be constructed and operated in a manner that facilitates safe dismantling, the maintenance of an Inventory of Hazardous Materials (IHM) throughout a ship’s operational life, and the development of a detailed Ship Recycling Plan (SRP) prior to decommissioning. The obligation to authorize, audit, and operate recycling facilities in accordance with safety and environmental standards is equally important (IMO, 2023).

After years of limited ratification, the Convention finally met the conditions for entry into force in June 2023, following critical endorsements by Bangladesh and Liberia—two countries with significant roles in shipbreaking and flag-state administration, respectively. Consequently, Bangladesh and Liberia have scheduled the HKC to become legally binding in 2025. Despite this milestone, the Convention has drawn notable criticism from environmental and labor rights organizations. One major concern is that the HKC permits the continuation of beaching practices, provided that certain safety and environmental conditions are formally “met.” However, these criteria are loosely defined, and enforcement mechanisms remain weak. The certification of compliance is largely entrusted to flag states, many of which lack robust oversight structures. Additionally, the Convention leans heavily on internal audits and market-based incentives rather than establishing an independent international monitoring regime (NGO Shipbreaking Platform, 2023).

It is worth noting, however, that some progress has been made within this framework. For example, India—despite being home to one of the largest beaching-based ship recycling industries—now hosts several facilities in Alang that are officially compliant with HKC requirements. These yards have improved their facilities and had outside checks to meet international standards, showing that even in busy ship dismantling areas, it's possible to follow some global best practices if there is enough market demand and support from regulations.

6.3 EU Ship Recycling Regulation (EU SRR)

The European Union Ship Recycling Regulation (EU SRR), officially Regulation (EU) No. 1257/2013, represents a more stringent and regionally binding framework compared to the Hong Kong Convention (HKC). Building upon the foundational principles of the HKC, the EU SRR introduces enhanced provisions aimed at ensuring both environmental protection and worker safety during the dismantling of ships. Since its application began in 2018, the regulation has been mandatory for all EU-flagged vessels exceeding 500 gross tonnage (GT), regardless of their trading routes. Moreover, the regulation indirectly extends its influence to non-EU-flagged vessels that call at EU ports, thereby incentivizing global compliance through port-state enforcement mechanisms (European Commission, 2024).

A central requirement of the EU SRR is that ship recycling must occur exclusively at facilities listed on the *European List of Approved Ship Recycling Facilities*. This list currently includes yards located within the EU and in select third countries such as Turkey, but notably excludes ship recycling facilities in India, even those that claim Hong Kong Convention compliance. In addition to this, all vessels under the regulation must maintain a certified and continuously updated *Inventory of Hazardous Materials* (IHM) throughout their operational life. Prior to dismantling, ships are also required to obtain a *Ready for Recycling Certificate*, confirming that all IHM documentation is in place and that recycling will occur at a compliant facility (European Commission, 2024).

Further reinforcing its regulatory scope, the 2024 amendment to the EU SRR—Regulation (EU) 2024/1157—introduced several key enhancements. These include the implementation of digital tracking systems for IHM compliance, increased inspection frequency of listed recycling yards, and the introduction of financial penalties targeting vessels registered under flags of convenience (FOCs) that attempt to evade regulatory obligations. These revisions underscore the EU's commitment to improving traceability, enhancing enforcement capabilities, and promoting environmentally sound recycling practices (European Commission, 2024).

Despite its strengths, the EU SRR is not without limitations. One of the primary weaknesses lies in its jurisdictional reach, as it does not apply to non-EU-flagged vessels that avoid EU ports altogether. Additionally, the limited number of yards approved under the European List has created capacity constraints, particularly when dealing with large fleets or oversized vessels that require specialized dismantling infrastructure. These bottlenecks can pose logistical challenges and may discourage compliance among cost-sensitive operators (OECD, 2021; NGO Shipbreaking Platform, 2023).

EU Ship Recycling Regulation (EUSRR) and the Absence of Ship Recycling Facilities in Greece

The EU Ship Recycling Regulation (EUSRR), formally adopted as Regulation (EU) No. 1257/2013, aims to ensure that ships flying the flag of a European Union Member State are dismantled in environmentally sound and safe conditions. The regulation implements the key provisions of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships while imposing additional EU-specific requirements. These include required impermeable floors, proper handling and treatment of dangerous waste (like asbestos, PCBs, and leftover oils), providing safety gear for workers, and keeping clear records through the Inventory of Hazardous Materials (IHM) (European Commission, 2023).

Although these provisions represent a significant advancement in environmental and occupational protection, they also render the establishment and operation of compliant recycling facilities considerably more expensive. The high cost of regulatory compliance—particularly related to infrastructure, environmental permitting, and hazardous waste treatment—creates a structural disadvantage for potential EU-based recycling operations compared to their counterparts in South Asia or even Turkey. Greece, despite owning the world's largest merchant fleet, has not established any ship recycling yard that meets the EUSRR's strict criteria. The lack of domestic capacity to dismantle vessels in accordance with these rules underscores the deep-rooted limitations of Greece's industrial and regulatory framework in this specific sector.

Several factors contribute to this absence. Firstly, the economic feasibility of setting up such facilities in Greece is severely constrained by elevated fixed costs. Land acquisition near ports is costly, skilled labor wages are significantly higher than in competitor regions, and the cost of environmental compliance is substantial. For instance, Turkey may charge around USD 800/ton for the disposal of hazardous materials like asbestos, whereas India may charge less than USD 300/ton for the same process, highlighting the disparity in the market (Hellenic Shipping News, 2024). Additionally, labor costs for unskilled workers are approximately USD 16–17 per day in Turkey, compared to USD 4–6 per day in South Asia, making competitive pricing in the Greek context virtually impossible.

Secondly, Greece's maritime infrastructure is historically geared toward ship repair, maintenance, and construction rather than ship dismantling. Facilities in regions such as Perama and Elefsis focus on traditional yard services and lack the necessary modifications—such as dry-docking space, gas-free zones, and containment systems—for end-of-life ship recycling. Furthermore, there is little incentive from either public policy or private stakeholders to redirect investments toward recycling, as the sector remains low-margin and highly dependent on volatile scrap metal markets.

Another decisive factor is bureaucratic inertia and environmental opposition. The permitting process in Greece for hazardous industrial operations is notoriously complex and time-consuming, often subject to prolonged environmental assessments, zoning disputes, and community resistance. Such complexity has discouraged serious private investment and delayed even preliminary feasibility studies for compliant facilities. The absence of coherent long-term state support or incentive frameworks further weakens Greece's position in the EU's circular economy agenda.

As a result, most Greek shipowners prefer to sell their end-of-life vessels to Turkish recycling yards in Aliağa, which provide an optimal balance between cost and regulatory compliance. As of 2024, 11 Turkish yards are listed on the European Commission's approved list of ship recycling facilities. These yards offer significantly lower costs compared to EU yards and are able to comply with both EUSRR and the Hong Kong Convention standards. Moreover, their geographic proximity to Greece makes them logistically convenient, reducing delivery time and fuel consumption while providing owners with a relatively clean exit from their environmental obligations.

Often, Greek-owned vessels are also registered under flags of convenience, such as Liberia, Panama, or the Marshall Islands. This practice enables shipowners to circumvent EU regulatory obligations by technically falling outside the jurisdiction of the EUSRR. End-of-life vessels are often sold to intermediaries known as "cash buyers" who, through temporary ownership and reflagging, reroute ships to South Asian yards without triggering compliance obligations. This practice of "flagging out" has become widespread and reflects a deeper flaw in the global governance of ship recycling—namely, the gap between regulatory intention and practical enforcement (Cyprus Shipping News, 2023; Politico.eu, 2022).

This gap highlights a fundamental challenge for the EUSRR and global policy efforts more broadly: the discrepancy between the jurisdictional scope of environmental legislation and the globalized nature of shipping. Unless compliance is enforced at the ownership or transaction level rather than merely through flag state control, it remains difficult to ensure that ships are recycled in facilities that align with the EU's sustainability and labor standards.

In conclusion, the absence of ship recycling facilities in Greece is not simply a matter of oversight but a manifestation of systemic misalignments—between regulation and competitiveness, between infrastructure and market incentives, and between national policy and global market realities. For the EUSRR to work well, we need to create additional strategies, such as working together internationally to enforce rules, providing financial rewards for environmentally friendly practices, and improving tracking systems for all stages of maritime assets.

6.4 Inventory of Hazardous Materials (IHM)

A core component of both the Hong Kong Convention (HKC) and the European Union Ship Recycling Regulation (EU SRR) is the implementation of the Inventory of Hazardous Materials (IHM). This inventory serves as a crucial documentation tool designed to identify, monitor, and manage the presence of hazardous substances throughout a ship's operational and dismantling phases. The IHM is divided into three parts. Part I details hazardous materials that are found onboard during the ship's service life, such as asbestos, polychlorinated biphenyls (PCBs), and ozone-depleting substances. Parts II and III are specific to the end-of-life phase and include records of operational waste generated and hazardous materials discovered during the dismantling process (IMO, 2023; European Commission, 2024).

To remain valid, the IHM must be maintained and updated throughout the vessel's entire lifecycle. It is subject to verification during inspections by flag state authorities and port state control regimes. Under EU SRR, all EU-flagged vessels are mandated to carry a certified IHM, while compliance is also increasingly encouraged within environmental, social, and governance (ESG) frameworks due to its relevance in sustainability reporting and regulatory transparency (Baumgartner & Rentschler, 2021). Despite its regulatory importance, the effective implementation of the IHM system faces several challenges. Many older vessels lack accurate or complete IHM documentation, particularly if they were constructed before such requirements became standard. In addition, there is often inadequate auditing capacity in developing countries where many ship recycling yards are located. This gap has contributed to concerns regarding the reliability of IHM compliance, especially in light of recent reports by the NGO Shipbreaking Platform (2023), which highlight instances of so-called "IHM laundering"—a practice involving falsified, incomplete, or deliberately misleading inventories designed to circumvent environmental and safety regulations.

Comparative Regional Compliance: EU, Turkey, and South Asia

The global ship recycling industry operates under markedly different regulatory, environmental, and labor frameworks depending on geographic location, creating both competitive imbalances and significant disparities in sustainability outcomes. The three primary regional clusters—European Union-approved facilities, Turkish yards (particularly in Aliağa), and South Asian yards in India, Bangladesh, and Pakistan—illustrate the spectrum of compliance and cost considerations that influence shipowner decision-making.

European Union ship recycling facilities, located primarily in Northern and Western Europe (e.g., Denmark, Norway, the Netherlands), are subject to the most stringent environmental and occupational safety standards. These yards implement impermeable flooring systems, advanced hazardous waste treatment facilities, mandatory use of personal protective equipment (PPE), and rigorous documentation practices, including adherence to the Inventory of Hazardous Materials (IHM). While these measures result in an environmentally sound and ethically aligned dismantling process, they also render such facilities significantly more expensive and often commercially unviable unless mandated by regulatory obligation (European Commission, 2023).

The relatively high labor costs, limited space for expansion, and small operational scale of most EU-approved yards mean that they are unable to absorb large volumes of end-of-life ships, particularly larger commercial vessels such as tankers or bulk carriers. This mismatch between regulatory ambition and operational capacity presents a barrier for shipowners seeking to recycle vessels within the EU and often redirects demand toward non-EU options.

In contrast, Turkey represents a hybrid model of regulation and cost-efficiency. The Aliağa region, home to 11 EU-listed ship recycling yards as of 2024, has positioned itself as a strategic intermediary. Turkish yards comply with the EU Ship Recycling Regulation and the Hong Kong Convention, offering structured working conditions, regulated handling of hazardous materials, and formal employment practices. Nonetheless, Turkey's cost base remains significantly lower than that of Northern Europe. Labor costs, for instance, average approximately USD 16–17 per day—more than South Asia but substantially less than in EU member states. The Turkish yards' proximity to major steel mills further enhances their efficiency, enabling them to supply processed steel directly to local re-rolling mills and construction sectors (ShippingInbox, 2023; ShipRecycling.com.tr, 2024).

This cost-regulation balance allows Turkish facilities to offer competitive dismantling prices, typically in the range of USD 200 per Light Displacement Tonne (LDT), without compromising environmental compliance. Furthermore, Turkey's geographical location close to major Mediterranean shipping routes and its inclusion on the EU's approved list make it a legally viable and logistically convenient solution for many European shipowners. As a result, Turkish yards have emerged as a preferred destination for those seeking to align economic and regulatory considerations.

At the other end of the spectrum lies South Asia, which dominates the global ship recycling industry in terms of volume, accounting for approximately 76% of the world's dismantled tonnage (Hellenic Shipping News, 2023). Yards in India, Bangladesh, and Pakistan offer the highest prices for scrap ships, often ranging between USD 380 and 420 per LDT. Substantial labor costs—ranging between USD 4 and 4–6 per day—and significantly relaxed environmental and occupational regulations drive these prices. Although some Indian facilities have adopted elements of the Hong Kong Convention, and limited infrastructural improvements have been introduced (e.g., semi-permanent cutting platforms, training programs), the widespread use of the beaching method continues to pose severe environmental risks, including contamination of soil and marine ecosystems (IMO, 2023; NGO Shipbreaking Platform, 2023).

Moreover, informal employment practices, lack of protective equipment, and minimal oversight mechanisms expose workers to substantial health and safety hazards. Despite growing international scrutiny and pressure from non-governmental organizations, enforcement remains inconsistent, particularly in Bangladesh and Pakistan, where the regulatory framework is weak or inadequately implemented. This environment enables cost arbitrage, where shipowners can access higher scrap values while externalizing the social and environmental costs of dismantling.

Turkey's operational model demonstrates that achieving a balance between environmental protection, worker safety, and commercial feasibility is possible. While Turkish yards may not match the price competitiveness of their South Asian counterparts, they represent a lawful, ethically defensible, and moderately priced alternative—especially for EU-flagged vessels or owners seeking ESG-compliant end-of-life asset management.

The regional comparison thus supports one of the core arguments of this thesis: that sustainable ship recycling cannot be achieved through regional regulation alone. The ship recycling industry will continue to gravitate towards jurisdictions with the lowest costs and weakest regulations without global harmonization of standards, along with monitoring mechanisms and incentive structures for compliance. As long as such disparities persist, environmental and human rights concerns will remain embedded within the economics of the sector, undermining the efficacy of instruments like the EU Ship Recycling Regulation and the Hong Kong Convention.

6.5 Flags of Convenience (FOCs) and Regulatory Circumvention

A persistent and widely recognized loophole in the global regulatory framework for ship recycling is the strategic exploitation of Flags of Convenience (FOCs). Many shipowners, particularly those aiming to minimize regulatory burdens and environmental obligations, deliberately re-flag their vessels to jurisdictions known for their weak oversight and lax enforcement, especially during the final phase of a ship's operational life. This tactic is often employed shortly before a vessel is sold for dismantling, enabling owners to sidestep the stricter environmental and labor standards imposed by international agreements and national regulations (OECD, 2021).

Common FOC states include Comoros, Palau, St. Kitts and Nevis, and Tuvalu—jurisdictions that, in many cases, are not parties to key international treaties such as the Hong Kong Convention (HKC), the Basel Convention, or the European Union Ship Recycling Regulation (EU SRR). This regulatory gap allows owners to engage in several circumvention strategies. These include last-minute reflagging of vessels prior to scrapping, the sale of ships to intermediaries or “cash buyers” who then assume legal ownership under a new flag and send the vessels to dismantling yards in unregulated environments, and the false classification of vessels as operational to avoid restrictions under the Basel Convention. Such practices not only weaken regulatory enforcement but also facilitate the continuation of environmentally harmful and ethically questionable dismantling procedures, particularly in South Asia (OECD, 2021; NGO Shipbreaking Platform, 2022).

The implications of these practices are far-reaching. They erode the effectiveness of international conventions, compromise the safety and well-being of workers in dismantling yards, and undermine the broader environmental objectives promoted by organizations such as the International Maritime Organization and the European Union. For instance, in 2021, more than 80 percent of vessels dismantled on the beaches of South Asia were flagged under FOCs at the time of scrapping, according to data compiled by the NGO Shipbreaking Platform (2022). Although the global regulatory landscape has made considerable strides—with instruments such as the Basel Convention, the HKC, and the EU SRR—compliance remains highly uneven. The combination of weak enforcement, strategic reflagging, and institutional capacity deficits in major recycling nations continues to challenge the legitimacy and effectiveness of these efforts. Nevertheless, the impending entry into force of the HKC offers a degree of optimism that greater international harmonization and enhanced accountability mechanisms may help promote more sustainable and transparent practices in the ship recycling industry.

Chapter 7: Labor and Health Conditions in Ship Recycling

The ship recycling industry is labor-intensive, especially in developing economies where manual dismantling is the norm. While the sector provides economic opportunities for thousands of workers, it is also marked by serious health risks, precarious employment conditions, and inadequate medical infrastructure. This chapter explores the socio-demographic profile of shipbreaking workers, their exposure to hazardous substances, accident and illness trends, and draws comparisons between labor conditions in South Asia and Turkey.

7.1 Worker Profiles and Migration Patterns in South Asia

Shipbreaking yards in India (Alang), Bangladesh (Chattogram), and Pakistan (Gadani) employ tens of thousands of workers, mostly from economically vulnerable and rural regions.

7.1.1 Demographics and Migration Patterns

The ship recycling industry in South Asia is heavily reliant on a large, mobile, and predominantly male workforce, with most workers originating from economically disadvantaged and rural regions. In India, the Alang-Sosiya Ship Recycling Yard employs an estimated 20,000 workers, the majority of whom are internal migrants from the states of Bihar, Uttar Pradesh, and Odisha. These workers are often drawn to Alang by the promise of higher wages than those available in their home regions, although the working conditions they encounter are frequently hazardous and poorly regulated (NGO Shipbreaking Platform, 2023).

In Bangladesh, the Chattogram shipbreaking area is home to a similarly large labor force, employing over 25,000 individuals. Most of these workers also come from rural, impoverished northern districts such as Dinajpur, Rangpur, and Gaibandha. The socio-economic vulnerability of this workforce is reflected in the limited access to social protection, occupational safety measures, and formal employment contracts. In Pakistan, the Gadani shipbreaking yard attracts a slightly smaller but no less vulnerable labor force. Workers here are primarily from the provinces of Balochistan and Punjab, and many operate without formal documentation or legal employment agreements, leaving them exposed to exploitative practices and without recourse to legal protections in the event of injury or wage disputes (NGO Shipbreaking Platform, 2023).

7.1.2 Employment Conditions

Employment conditions for workers in ship recycling yards across South Asia are predominantly informal, with the vast majority of laborers lacking written contracts, access to social security systems, or any form of health or accident insurance. This informality not only perpetuates job insecurity but also denies workers legal protection in cases of injury, wage disputes, or hazardous exposure. Wages in dismantling hubs such as Alang, Chattogram, and Gadani typically range from approximately USD 3 to 6 per day, depending on the worker's level of skill, experience, and the specific tasks assigned. These wages, while often higher than those in rural agriculture or informal urban work in their home regions, remain well below international labor standards and fail to reflect the occupational risks involved (NGO Shipbreaking Platform, 2023).

Living conditions for these workers are similarly precarious. Housing is usually arranged in the form of temporary dormitories or labor camps located near the yards. These accommodations often lack basic infrastructure, including proper sanitation, ventilation, and access to clean drinking water. Overcrowding, poor hygiene, and limited access to medical care are common, compounding the risks posed by the physically demanding and hazardous nature of the work. While conditions in some Turkish facilities, such as those in Aliaga, are comparatively better due to stricter national regulations and partial alignment with European Union standards, detailed comparative wage and housing data for those facilities remain limited in publicly available sources (Baumgartner & Rentschler, 2021; NGO Shipbreaking Platform, 2023).

7.2 Exposure to Hazardous Materials

The majority of end-of-life ships contain hazardous substances embedded in their structure or trapped in tanks, paint, and insulation.

7.2.1 Common Hazardous Substances

Ship recycling exposes workers to a wide range of hazardous substances embedded within the structure of vessels, many of which pose serious long-term health risks. One of the most pervasive and dangerous materials encountered is asbestos, which is commonly found in insulation, gaskets, and pipe lagging. When disturbed during dismantling operations, asbestos fibers become airborne and can be easily inhaled, potentially leading to asbestosis, lung cancer, and mesothelioma—diseases with prolonged latency periods and high mortality rates. Similarly, polychlorinated biphenyls (PCBs), often present in transformers, capacitors, and certain marine paints, are known to interfere with hormonal systems and are associated with neurological damage and several forms of cancer.

Other toxic substances frequently encountered include polycyclic aromatic hydrocarbons (PAHs), which are found in oil residues and burnt materials. Prolonged exposure to PAHs, either through skin contact or inhalation, is known to be carcinogenic. Tributyltin (TBT), a biocide formerly used in anti-fouling paints, is particularly harmful to both marine ecosystems and human health. TBT is linked to immune system suppression, reproductive defects, and endocrine disruption. Despite the presence of these substances, workers in South Asian yards often dismantle ships using manual gas-cutting techniques without adequate personal protective equipment. This lack of protection results in the direct inhalation of toxic fumes and dermal absorption of hazardous contaminants, contributing to elevated risks of chronic illness and occupational disease (Baumgartner & Rentschler, 2021).

7.2.2 Occupational Exposure Pathways

During ship dismantling, several routine tasks expose workers to significant toxicological risks. Gas torch cutting, commonly used to break down steel structures, emits a range of airborne toxins, including metal fumes and combustion byproducts, which are frequently inhaled by workers operating without proper respiratory protection. Another hazardous practice involves the manual cleaning of tanks, where workers are exposed to residual hydrocarbons, often in confined spaces with poor ventilation. These substances pose risks of both acute toxicity and long-term respiratory complications.

Equally concerning is the bare-hand handling of aged insulated pipes and electrical cables, which often contain materials such as polychlorinated biphenyls (PCBs) and lead. Direct dermal contact with these substances increases the likelihood of skin absorption and long-term contamination, particularly in environments lacking adequate hygiene facilities or safety training. The cumulative exposure to such harmful agents demonstrates the pressing need for robust occupational health safeguards in ship recycling yards, particularly in South Asia, where safety regulations are inconsistently enforced (Baumgartner & Rentschler, 2021).

7.3 Accidents, Diseases, and Health Infrastructure Gaps

South Asian shipbreaking yards consistently rank among the world's most dangerous industrial environments.

7.3.1 Accident Statistics

Accident and fatality rates in ship recycling yards across South Asia remain alarmingly high, highlighting the ongoing deficiencies in occupational safety practices. In Bangladesh, official data from 2022 reported 14 fatalities and 37 serious injuries in Chattogram's shipbreaking yards. However, these figures are widely believed to underestimate the true scale of the problem due to systemic underreporting and the absence of transparent monitoring mechanisms (NGO Shipbreaking Platform, 2023). Similarly, in India, nine workers were confirmed dead in 2021 at the Alang-Sosiya yard, with causes including falls from height, explosions, and inhalation of toxic gases—often resulting from unmarked confined spaces or insufficient gas-free certifications (Times of India, 2021).

One of the most devastating incidents occurred in Pakistan in 2016, when an explosion aboard an oil tanker in Gadani resulted in the deaths of 28 workers and injuries to more than 50 others. The disaster drew international attention to the dangers inherent in dismantling oil-bearing vessels without proper degassing and hazard assessment protocols. Such accidents are frequently attributed to a combination of inadequate safety training, lack of access to essential protective equipment such as gloves, helmets, and harnesses, and the general absence of standardized hazard detection and mitigation systems. These persistent gaps not only place workers at severe risk but also undermine broader efforts to align the industry with internationally accepted safety norms (NGO Shipbreaking Platform, 2023; Times of India, 2021).

7.3.2 Occupational Illnesses

Workers employed in ship recycling yards—particularly those engaged in metal cutting, tank cleaning, and dismantling operations—face a heightened risk of chronic occupational illnesses due to sustained exposure to hazardous substances and harsh environmental conditions. Respiratory diseases are particularly prevalent, with conditions such as chronic bronchitis, asthma, silicosis, and tuberculosis frequently reported among workers who inhale dust, metal particulates, and toxic fumes during cutting activities in poorly ventilated areas. These respiratory risks are compounded by the absence of adequate personal protective equipment (PPE), such as respirators and filtration masks.

In addition to respiratory ailments, workers often suffer from a range of dermatological conditions. Frequent and unprotected contact with chemical residues—including fuel oils, rust inhibitors, and marine coatings—can lead to chemical burns, allergic reactions, and various forms of dermatitis. Also, being in loud environments for a long time, where machines are cutting and grinding without sound barriers or ear protection, can gradually cause workers to lose their hearing. These cumulative health impacts indicate that it's time for more rigorous enforcement of health and safety protocols, especially in regions where informal labor practices and weak regulatory oversight are commonplace (Baumgartner & Rentschler, 2021).

7.3.3 Health Infrastructure Gaps

Healthcare infrastructure within ship recycling yards—particularly in South Asia—remains severely underdeveloped, further exacerbating the risks faced by workers operating in these hazardous environments. Only a small number of dismantling facilities maintain on-site medical clinics, and those that do often lack adequate staffing, equipment, and medication to address even routine injuries. Most emergency responses are rudimentary, often transporting injured workers to distant government hospitals several kilometers away. The absence of well-equipped and timely medical intervention increases the severity of injuries and reduces the likelihood of full recovery.

Moreover, the lack of structured occupational health monitoring represents a significant gap in the industry's risk management practices. Periodic health screenings for early detection of chronic conditions—such as respiratory illnesses, chemical exposure, or hearing loss—are rarely conducted. As a result, workers typically do not undergo regular medical assessments, and there is virtually no systematic collection of long-term occupational health data. This deficit in preventive care and record-keeping impedes both epidemiological analysis and the formulation of evidence-based health and safety interventions (OECD, 2021).

7.4 Labor Conditions in Turkish Yards: The Case of Aliaga

In contrast to South Asia, Turkey's Aliaga ship recycling zone offers a model of relatively safe and regulated labor conditions.

7.4.1 Worker Profile

The ship recycling yards in Aliaga, Turkey, employ approximately 1,000 to 1,500 workers annually. Unlike the informal and unregulated labor conditions often seen in South Asia, the workforce in Aliaga is formally registered and unionized. Workers benefit from the protection of national labor legislation and occupational health and safety laws, ensuring legal safeguards concerning wages, working hours, social security, and workplace rights. This regulatory framework contributes to improved job security and enables collective bargaining mechanisms, distinguishing Aliaga from many other global ship recycling hubs.

7.4.2 Safety Measures and Training

Occupational safety is a central pillar of operations in Aliaga's dismantling facilities. The use of personal protective equipment (PPE) is mandatory for all workers, and regular safety training is conducted under the supervision of certified engineers and technical staff. This training ensures that workers are aware of and capable of adhering to safe dismantling procedures. Enforcing a gas-free certification process is a crucial safety requirement, mandating its completion before authorizing any cutting operation. This protocol minimizes the risk of explosions and toxic gas inhalation, common hazards in shipbreaking.

7.4.3 Medical Infrastructure

Aliaga also demonstrates significant advancements in occupational health infrastructure. Each facility is equipped with an on-site medical clinic, and the presence of first-aid personnel is mandatory throughout operational hours. Emergency preparedness, including drills for firefighting, oil spill containment, and evacuation procedures, is regularly integrated into yard protocols. In addition, annual health checks and systematic tracking of occupational diseases are embedded within human resources practices, ensuring early detection and long-term monitoring of worker health.

7.4.4 Accident and Health Outcomes

As a result of these preventive and responsive measures, the incidence of workplace fatalities in Aliaga remains exceptionally low, and the overall injury rate is markedly lower than in shipbreaking yards across South Asia. Health insurance coverage, paid medical leave, and legally mandated compensation provide further support to workers in the event of injury or work-related illness. Aliaga follows the European Union Ship Recycling Regulation (EU SRR) and meets the standards of the Hong Kong Convention (HKC), making it a top choice for shipowners who want to responsibly and ethically recycle their ships.

The human cost of ship recycling is deeply unequal across regions. In South Asia, informal labor, hazardous exposure, and poor health infrastructure create dangerous and degrading work environments. By contrast, Turkey's regulated yards offer a safer, more humane model—albeit at higher operational expenses. As international conventions like the HKCand EU SRR gain traction, improving labor conditions in developing countries remains one of the critical challenges for sustainable ship recycling.

Labour Costs and Employment Conditions

Labour costs and working conditions constitute a fundamental differentiator among ship recycling destinations, directly influencing both the financial viability and ethical considerations associated with the dismantling process. In the leading South Asian ship recycling hubs—namely Alang (India), Chattogram (Bangladesh), and Gadani (Pakistan)—daily wages for unskilled or semi-skilled workers typically fall between USD 4 and 6. These wage levels reflect broader regional economic conditions and are often facilitated by weak enforcement of labour laws, the prevalence of informal employment arrangements, and the absence of trade unions or collective bargaining structures (NGO Shipbreaking Platform, 2023).

Employment in these yards is generally characterised by high physical risk, lack of formal contracts, and insufficient access to social protections. Workers are frequently migrants from impoverished rural areas and may lack training in handling toxic substances or operating heavy machinery. Personal protective equipment (PPE) is often either unavailable or inadequately enforced, which exacerbates occupational health hazards such as exposure to asbestos fibres, lead-based paints, polychlorinated biphenyls (PCBs), and residual hydrocarbon vapours (Baumgartner & Rentschler, 2021).

By contrast, Turkish ship recycling yards—especially those located in the Aliağa region—operate within a more regulated framework that aligns with both national legislation and international environmental and labour standards. Daily wages in Turkey average between USD 16 and 17, more than triple those in South Asia (Hellenic Shipping News, 2023). Although this increases labour costs, it also contributes to safer and more structured working environments. Turkish yards typically require formal employment contracts, enforce labour inspections, and provide workers with standardized safety equipment and occupational health coverage.

Moreover, regular health checks, insurance schemes, and training programmes are more likely to be implemented in Turkish facilities, supported by periodic audits conducted by EU or IMO-aligned bodies. This contrast in labour regimes has a direct impact on cost structures: South Asian yards may offer higher scrap prices per LDT due to reduced human capital costs, but these come at the expense of workplace safety and long-term health consequences for workers—externalities not accounted for in most market pricing models (IMO, 2023; NGO Shipbreaking Platform, 2023).

In terms of policy implications, this labour cost asymmetry illustrates the global dilemma faced by regulatory bodies: how to reconcile economic efficiency with ethical and sustainable labour practices in an industry dominated by cost-sensitive actors. Without harmonized international enforcement mechanisms, this cost gap perpetuates a race to the bottom in terms of labour rights.

Environmental Compliance Costs

Environmental protection requirements and the costs associated with their implementation differ significantly among ship recycling jurisdictions. In Turkey, regulatory frameworks derived from both domestic environmental law and EU standards require yards to meet strict operational benchmarks. These include impermeable flooring to prevent soil contamination, sealed drainage systems to capture toxic runoffs, and the safe segregation and disposal of hazardous waste such as polychlorinated biphenyls, asbestos, and heavy metals (European Commission, 2023).

These environmental safeguards contribute to elevated cost structures. For example, the treatment and disposal of asbestos—a common hazardous material on older vessels—costs approximately USD 800 per metric ton in Turkish yards. This cost includes certified collection, containment, and transport to approved disposal facilities. In contrast, comparable disposal operations in India are estimated at only USD 300 per ton due to laxer enforcement, lower labor costs, and often inadequate end-of-life treatment procedures (ShipRecycling.com.tr, 2024).

Similarly, the dismantling process in Turkey is typically conducted in designated dry berths with containment infrastructure, while South Asian yards still rely heavily on the "beaching" method, whereby ships are run aground and dismantled directly on tidal mudflats. This practice significantly increases the risk of marine and soil contamination and complicates the safe extraction of hazardous materials (Mikelis, 2013). Although India has made some advances in implementing the Hong Kong

International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC), enforcement remains uneven and does not uniformly reach the smaller yards.

The elevated compliance costs in Turkey affect operational margins and influence the prices that yards can offer to shipowners. While Turkish yards are capable of achieving high material recovery rates—over 90% of ship mass is typically recycled—they must do so under strict environmental controls, which diminishes the price competitiveness of their bids compared to South Asian facilities (ShipRecycling.com.tr, 2024).

Nevertheless, Turkey's adherence to international conventions and EU ship recycling regulations positions it as a viable model for balancing environmental sustainability with economic feasibility. Its inclusion on the European Commission's list of approved recycling facilities demonstrates its capacity to integrate advanced environmental protection mechanisms while still offering cost-effective services—particularly when compared to the often prohibitively expensive EU-based yards.

This divergence in environmental compliance costs further illustrates the value of harmonized global standards and monitoring, without which environmentally responsible yards are placed at a competitive disadvantage. It also emphasizes that there must be incentive mechanisms—such as green certification schemes or ESG-linked financing—to support sustainable practices in this sector.

Chapter 8: The Economics of Ship Recycling

The multibillion-dollar industry of ship recycling intersects with maritime transport, global steel markets, and resource recovery. From the perspective of a shipowner, recycling represents the final opportunity to extract residual value from an aging asset, while for recycling yards, it is an opportunity to profit from metal recovery, resale of components, and labor arbitrage. This chapter analyzes the economic actors, pricing mechanisms, macroeconomic influences, and resource efficiency of the recycling process.

8.1 The Role and Business Model of Cash Buyers

At the center of the international ship recycling economy stands a pivotal intermediary figure: the cash buyer. Cash buyers are private entities that purchase end-of-life vessels from shipowners and manage the logistics, legal formalities, and commercial risks involved in delivering the ship to a dismantling facility—most commonly in South Asia. This model simplifies the transaction for the original shipowner, who often prefers to avoid direct involvement in the regulatory and reputational complexities of shipbreaking.

8.1.1 Identity and Practices of Cash Buyers

Cash buyers typically acquire vessels on an “as-is, where-is” basis, assuming responsibility for any remaining voyage, documentation, or legal transfer issues. Their business model involves a high level of logistical and regulatory maneuvering, including reflagging the vessel—often to a Flag of Convenience (FOC)—and arranging for its final voyage to a designated yard, such as those located in Alang (India), Chattogram (Bangladesh), or Gadani (Pakistan). Notable firms operating in this sector include Global Marketing Systems (GMS), Priya Blue, and Wirana Shipping Corporation, which collectively dominate a significant portion of global shipbreaking transactions (NGO Shipbreaking Platform, 2023).

A notable characteristic of cash buyers is that the vessels they acquire are often not located near the recycling yards at the time of sale. Instead, they purchase ships from distant regions like Europe, the Middle East, or East Asia. Delivery to the final dismantling site may involve a direct single-voyage route, or, often, a delay of several months during which the vessel undertakes two or three commercial voyages under the new ownership. This practice serves dual purposes: generating additional freight revenue and obscuring the intent to scrap, particularly in cases where the selling party is a European or publicly scrutinized company. Such maneuvers allow the cash buyer to present the vessel's final journey as part of a commercial lifecycle, thereby masking its scrapping destination and limiting legal accountability under frameworks such as the Basel Convention or the EU Ship Recycling Regulation.

Furthermore, cash buyers often play a facilitative role for the final shipowner, enabling a form of reputational "cleansing." By transferring the vessel to a third-party buyer—who subsequently reflags and delivers the ship to a yard that may or may not meet international environmental and labor standards—the original owner can publicly distance itself from the consequences of the vessel's dismantling. In effect, the cash buyer absorbs the commercial and legal responsibility of the end-of-life phase while shielding the seller from regulatory scrutiny and reputational damage (Baumgartner & Rentschler, 2021).

8.1.2 Revenue Streams of Cash Buyers

Cash buyers generate revenue primarily by reselling acquired vessels to ship recycling yards at a higher price than the initial purchase value. This price differential serves as the principal source of profit and reflects the cash buyer's assumption of commercial, logistical, and regulatory risks. Beyond the resale margin, cash buyers may also extract supplementary value by salvaging onboard equipment and machinery prior to delivery. Components such as diesel generators, pumps, electronic systems, navigation equipment, and even furniture are often removed and sold separately in secondary markets, contributing to overall profitability.

In some cases, more sophisticated cash buyers engage in financial engineering practices to manage their exposure to price volatility in the scrap metal market. This includes the use of forward contracts and informal hedging arrangements based on forecasts of scrap steel prices and demand dynamics in regional rolling mills. Such practices allow them to secure better margins, particularly in markets where price fluctuations can significantly affect profitability. These strategies underline the increasingly financialized nature of the ship recycling business and demonstrate how cash buyers have evolved into complex commercial actors rather than mere intermediaries (Baumgartner & Rentschler, 2021).

8.2 Price Formation in Ship Recycling

The financial valuation of a ship destined for recycling is typically determined using its Light Displacement Tonnage (LDT)—a metric that represents the weight of the ship excluding all cargo, fuel, ballast water, and provisions. The selling price is generally quoted in US dollars per LDT (USD/LDT) and varies based on several key factors, including global steel prices, vessel type, onboard recoverable materials, and the geographical location of the recycling yard. Prices are often higher in countries with lower labor and compliance costs, such as India and Bangladesh, although yards in Turkey and the EU may offer a discount premium for "green recycling" practices compliant with the EU Ship Recycling Regulation (EU SRR) or the Hong Kong Convention.

8.2.1 Key Determinants of Scrap Price

Factor	Explanation
LDT	Determines the base scrap weight. Older tankers and bulkers often exceed 20,000 LDT.
Scrap Steel Rate ($/LDT)	Fluctuates daily based on local and global steel demand (typically $400–$600/LDT).
Reusable Equipment	Valuables such as generators, electronics, and furniture increase total value.
Flag and IHM status	Vessels with Hong Kong/IHM documentation may fetch premiums if destined for certified yards.

The market value of a ship sold for recycling is primarily driven by a set of economic and technical factors, the most fundamental of which is the vessel's Light Displacement Tonnage **(LDT)**. This metric defines the base weight of the ship in tonnes—excluding cargo, fuel, ballast water, and stores—and serves as the standard unit for calculating scrap value. Older tankers and bulk carriers frequently exceed 20,000 LDT, and thus their dismantling yields a substantial volume of recoverable steel.

Another critical determinant is the scrap steel rate, which is typically quoted in US dollars per LDT (USD/LDT). This rate fluctuates according to regional and global supply-demand dynamics in the steel market and is influenced by factors such as infrastructure spending, construction activity, and energy prices. At present, typical scrap rates range between USD 400 and 600 per LDT, although higher rates may apply during commodity upswings (Baumgartner & Rentschler, 2021).

The value of reusable equipment also plays a significant role in price determination. Shipboard assets such as diesel generators, pumps, electronics, navigation instruments, and even furniture can be extracted prior to or during the dismantling process and sold in second-hand maritime or industrial markets. These components can add considerably to the vessel's net value, especially when properly documented and in working condition.

Lastly, regulatory documentation and flag status can influence pricing outcomes. Ships equipped with a certified Inventory of Hazardous Materials (IHM) or classified under the Hong Kong Convention may attract premiums if sold to compliant yards—such as those included on the European List of Approved Ship Recycling Facilities. Buyers targeting environmentally certified dismantling sites may pay more for vessels that are already compliant to reduce administrative burdens and ensure smooth processing under EU or IMO regulations.

For illustrative purposes, consider a bulk carrier with an LDT of 22,000 tons sold at a scrap rate of USD 500/LDT. This transaction would yield a gross return of USD 11 million before deducting associated costs such as brokerage fees, delivery expenses, and flag-related administrative charges. Such a calculation underscores the financial significance of these variables in shaping the economics of ship demolition.

8.3 Influence of LME Prices and Mill Demand

The pricing of scrap steel derived from ship recycling is closely tied to broader trends in global commodity markets, most notably those reflected on the London Metal Exchange (LME). Fluctuations in LME-listed ferrous metals, such as rebar, billets, and hot-rolled coils (HRC), are often used as proxies for scrap steel demand. When iron ore prices surge, steel manufacturers frequently respond by substituting primary inputs with secondary ones, including recycled steel from decommissioned ships. This shift reduces production costs and contributes to emissions reductions, aligning with environmental performance targets across the industry (Mikelis, 2013).

Local mill demand further shapes price dynamics, particularly in South Asian countries such as India, Pakistan, and Bangladesh. In these regions, steel re-rolling mills rely heavily on ship scrap, which can account for as much as 20 to 40 percent of their raw material input. The mills typically favor thick plates salvaged from ship hulls, which are easily repurposed into construction-grade materials. Seasonal patterns, such as post-monsoon construction booms in India, also influence demand levels and the price competitiveness of yard bids. Additionally, local customs duties, regulatory quotas, and import tariffs play a decisive role in shaping the volume and value of scrap steel procurement from dismantling facilities (Clarksons Research, 2023).

In Turkey, by contrast, the downstream market for ship-derived steel exhibits greater diversification. While thick plates are similarly recovered and used for industrial purposes, they are not exclusively routed to re-rolling mills or construction suppliers. A portion of this material is also sold to sectors such as infrastructure fabrication, heavy equipment manufacturing, or even exported as a semi-finished product, reflecting a broader industrial base and more advanced scrap logistics infrastructure compared to most South Asian contexts.

This difference shows how global market trends, local rules, and the features of the industrial system work together to influence the value and movement of recycled steel from decommissioned ships.

8.4 Energy and Material Input/Output Analysis

Process	Typical Energy Input
Ship dismantling (manual/mechanical)	50–200 MJ/tonne (mostly diesel-powered cranes, torches)
Re-melting scrap (Electric Arc Furnace)	~600–700 MJ/tonne of steel
BOF from iron ore	~15,000–20,000 MJ/tonne

The ship recycling process is widely recognized as a significantly more energy-efficient alternative to primary steel production, particularly when compared to steelmaking via the basic oxygen furnace (BOF) route. This distinction highlights the critical role of ship dismantling in the broader framework of circular economy strategies and decarbonization policies.

8.4.1 Energy Inputs

Energy consumption across various steel recovery methods varies substantially. Manual and mechanical ship dismantling typically requires between 50 and 200 megajoules (MJ) per ton, depending on the scale of operations and the equipment used—such as diesel-powered cranes and gas torches. Following dismantling, the re-melting of recovered scrap steel in an electric arc furnace (EAF) consumes approximately 600 to 700 MJ per ton of steel produced. In stark contrast, primary steel production from iron ore via the BOF process can require between 15,000 and 20,000 MJ per ton (IEA, 2022). These figures demonstrate that ship recycling, when integrated into secondary steel production, can result in energy savings of up to 90% relative to conventional steelmaking.

8.4.2 Emissions and Waste Flows

The energy advantages of ship recycling translate directly into reduced greenhouse gas emissions. The carbon footprint associated with producing one ton of recycled steel is approximately 0.4 to 0.6 tons of CO_2, compared to 1.9 to 2.2 tons of CO_2 for steel derived from virgin materials using the BOF process (IEA, 2022). Moreover, recycling generates substantially less slag and chemical waste. However, this environmental benefit is offset by the persistent risk of hazardous residuals, particularly in dismantling processes that lack robust containment measures. Substances such as lead-based paint flakes and tributyltin (TBT) from antifouling coatings pose ongoing challenges for safe waste management in less-regulated yards.

8.5: The Circular Value of Ship Recycling

Beyond the recovery of ferrous metals, ship recycling also yields significant non-steel economic benefits. Valuable materials such as aluminum, copper, and brass are extracted and sold separately to specialized scrap processors or secondary manufacturers. In dismantling hubs such as Bhavnagar in India, secondhand maritime markets flourish with the resale of furniture, electronics, life-saving appliances, and other reusable components salvaged from decommissioned vessels. Often, used machinery—including generators, compressors, and pumps—is refurbished for continued use in coastal fishing fleets or in small-scale industrial applications.

The economic multiplier effect of ship recycling is particularly evident in developing countries. In Bangladesh, for instance, the industry supports a network of downstream activities, including steel re-rolling mills, foundries, transport and logistics providers, and informal retail markets. These interlinked sectors benefit from the steady supply of raw materials and components, which originate almost exclusively from dismantled vessels. The entire value chain—from shipowner to yard operator to scrap processor—demonstrates the deeply embedded role of ship recycling in regional industrial ecosystems.

Ultimately, the economics of ship recycling are shaped by a diverse set of stakeholders, including shipowners, cash buyers, yard operators, and steel mills. The financial viability of a demolition sale depends on scrap pricing, the vessel's Light Displacement Tonnage (LDT), and prevailing market conditions. As global environmental regulations tighten and decarbonization strategies accelerate, the demand for recycled steel is likely to increase. This shift will further reinforce the strategic and economic relevance of ship recycling within both the maritime sector and the circular economy at large.

Economic Dynamics of Ship Recycling

Proximity to Steel Industries and Scrap Market Integration

A critical determinant of the economic efficiency of ship recycling operations is the proximity of dismantling yards to steel mills and scrap-consuming industries. This spatial linkage directly affects logistics costs, turnaround times, and the extent of value capture from recycled materials. Turkish recycling facilities in Aliağa and their South Asian counterparts in Alang (India) and Chattogram (Bangladesh) exemplify optimal integration into domestic metallurgical and construction supply chains. These yards are strategically located near major steel re-rolling mills and industrial consumers of scrap metal, facilitating a just-in-time delivery model that lowers transportation expenses and enhances processing efficiency (ShippingInbox, 2023).

This geographical synergy ensures that recovered steel plates, beams, and fittings are rapidly transferred into domestic re-rolling furnaces, reducing inventory lags and maximizing resale value. In contrast, European ship recycling yards—particularly those in Northern Europe—often face fragmented scrap market ecosystems. Many lack immediate downstream steel integration, necessitating additional logistical arrangements for inland transportation or export, which erodes cost competitiveness. Additionally, in the EU, the need for steel is usually satisfied by existing supply chains that use Electric Arc Furnace (EAF) inputs and new scrap from industrial leftovers, which puts recycled ship steel at a disadvantage (Clarksons Research, 2024).

Thus, the co-location of ship recycling and steel industries in Turkey and South Asia improves material recovery rates and reinforces a circular economy model, where end-of-life vessels are efficiently reincorporated into national infrastructure development projects.

Scrap Price Determinants and Market Behavior

Scrap prices, usually quoted in USD per Light Displacement Tonne (LDT), are influenced by a complicated combination of global commodity prices, local labor and compliance costs, and vessel-specific characteristics. From 2011 to 2024, the average offered prices for end-of-life ships varied as follows: South Asia consistently recorded the highest levels, between USD 380 and 420/LDT; Turkish yards averaged around USD 200/LDT; while many EU-based facilities offered significantly lower rates, averaging approximately USD 130/LDT (Hellenic Shipping News, 2023).

Several factors account for this divergence. South Asian yards benefit from ultra-low labor costs, minimal environmental enforcement, and efficient informal markets for component resale. Furthermore, regulatory barriers in these countries are relatively relaxed, allowing for beaching practices that reduce infrastructure expenditure and enhance steel extraction rates. Turkish yards, while offering lower prices than South

Asia, maintain more advanced environmental and labor safeguards, leading to higher operational costs but greater regulatory alignment with international standards (ShipRecycling.com.tr, 2024).

Scrap prices are also sensitive to global steel market trends. Demand for construction-grade rebar, billets, and hot-rolled coils—key products derived from recycled ship steel—fluctuates in tandem with infrastructure spending cycles, particularly in Asia and the Middle East. Oil prices and freight rates (as captured by indices such as the Baltic Dry Index) further influence scrap prices by shaping the opportunity cost of keeping vessels in service versus sending them for demolition. As shown in Chapter 9, our analysis found that there are moderate connections between the Baltic Dry Index (BDI) and Brent oil prices with average scrap prices, indicating that larger economic trends significantly affect market behavior.

Profitability Considerations for Shipowners

For shipowners, the selection of a dismantling destination is fundamentally a financial calculus, tempered by compliance obligations and reputational considerations. Vessels with large steel volumes, particularly older bulk carriers and tankers, can generate substantial returns if sold to South Asian facilities that offer the highest LDT-based valuations. These offers, driven by reduced labor and environmental costs, can result in a financial windfall for owners—often exceeding USD 1 million more than equivalent sales in the EU market for larger vessels (Clarksons Research, 2024).

However, this profit-driven model is increasingly being challenged by regulatory and stakeholder pressures. ESG-conscious investors, charterers, and institutional financiers are beginning to scrutinize ship recycling decisions under broader corporate sustainability frameworks. Failure to adhere to responsible recycling practices may expose shipowners to reputational risks, exclusion from sustainable finance schemes, and even legal liabilities under emerging due diligence laws in Europe and OECD countries (European Commission, 2023; Mikelis, 2022).

In this context, Turkey emerges as a viable middle-ground solution. While offering lower prices than South Asia, Turkish yards listed under the EU Ship Recycling Regulation provide sufficient scale, competitive rates, and regulatory assurance. This makes them particularly attractive to European owners seeking to comply with legal mandates without absorbing the full cost burden of recycling in Northern Europe.

Moreover, several Turkish yards have adopted sustainable operational models, including closed-loop drainage systems, safe asbestos handling, and material traceability protocols. Their integration into global ESG assessments positions them as key enablers of responsible ship decommissioning, bridging the cost-regulation divide that continues to define the global recycling landscape.

Chapter 9: Quantitative Analysis: Econometric Model

This chapter presents the quantitative component of the research, aiming to identify and explain the macroeconomic variables and crisis-related factors that influence the pricing of ships at the point of their demolition. The approach draws on econometric tools to analyze the relationship between scrap prices and key maritime indicators, such as freight market conditions and fuel prices. In doing so, the chapter not only contributes to the academic literature on maritime economics but also offers useful suggestions for shipowners, recyclers, and policymakers navigating a volatile global market.

9.1 Data Sources and Variable Construction

The analysis is based on a monthly time series dataset that covers the period from 2011 to 2024. The dependent variable in the econometric model is the scrap price, measured in US dollars per Light Displacement Tonne (LDT). We primarily source the data, which differentiates between dry and wet tonnage, from industry shipbroker reports and Clarksons Research.

The independent variables include:

- The Baltic Dry Index (BDI) serves as a widely used proxy for global dry bulk shipping demand and freight rate levels.
- The price of Brent Crude oil serves as a benchmark for bunker fuel costs and overall economic sentiment.
- Major macroeconomic disruptions like the 2008 financial crisis, the COVID-19 pandemic (2020), and the global inflationary pressure due to the war in Ukraine are accounted for by a dummy variable.

All time series were checked for consistency, and transformations such as first-differencing were applied where necessary to ensure stationarity and avoid spurious regression.

9.2 provides the model specification and an explanation of the time index.

We propose the following Ordinary Least Squares (OLS) model to formally examine the influence of these factors on demolition pricing:

$$Scrap\_Price\_t = \beta 0 + \beta 1BDI\_t + \beta 2Oil\_t + \beta 3CrisisDummy\_t + \varepsilon\_t$$

In this equation:

- Scrap_Price_t refers to the average monthly scrap price at time t.
- BDI_t is the corresponding value of the Baltic Dry Index.
- Oil_t denotes the Brent crude oil price in the same period.
- CrisisDummy_t takes a value of 1 if a major global disruption occurs at time t and 0 otherwise.
- ε_t is the residual term capturing unexplained variation.

The subscript "t" denotes time, expressed in months. This temporal notation enables the analysis to track how the pricing dynamics of scrapped ships reflect changes in economic conditions over time.

9.3 Methodological Framework

The model is estimated using OLS regression. Several diagnostic tests are conducted to ensure the robustness of the findings. These tests check for problems like multicollinearity with the Variance Inflation Factor (VIF), heteroskedasticity with the Breusch–Pagan test, and autocorrelation with the Durbin–Watson statistic. The normality of the residuals is tested via the Jarque–Bera test.

Where diagnostic issues are identified, adjustments such as robust standard errors are employed to improve the reliability of coefficient estimates.

9.4 Hypotheses and Expected Effects

We design the model to test the following hypotheses:

First, it is expected that a higher Baltic Dry Index, indicating stronger demand for shipping capacity and higher freight rates, will lead to a decline in the volume of ship recycling and therefore negatively correlate with scrap prices. Owners are less likely to scrap vessels during profitable market periods.

Second, increases in oil prices may lead to the accelerated scrapping of older, less fuel-efficient ships, exerting upward pressure on scrap prices. Thus, a positive relationship is anticipated between Brent crude prices and scrap valuations.

Third, the introduction of a crisis dummy allows the model to isolate the price effects of extraordinary disruptions, such as global recessions or pandemics. It is expected that such events will result in temporary spikes in demolition activity and corresponding shifts in pricing.

Initial trends in the dataset appear to support these assumptions. For instance, during the COVID-19 crisis, a marked decline in freight rates coincided with increased scrapping activity and fluctuations in scrap prices.

9.5 Limitations and Considerations for Future Research

While the model provides a structured framework for understanding the determinants of scrap pricing, it is not without limitations. The use of a linear model imposes restrictions that may not capture the complex, possibly nonlinear interactions between variables. Additionally, lag effects, where past economic conditions influence current decisions, are not explicitly modeled here.

Furthermore, the current dataset does not include detailed information on the characteristics of individual ships or the operational capacity of recycling yards, both of which could significantly affect pricing outcomes. Future research could benefit from panel data models that combine time-series and cross-sectional data for more profound insights.

Despite these limitations, the model presented in this chapter contributes meaningfully to the quantitative analysis of ship recycling markets. It demonstrates that macroeconomic indicators and crisis events exert measurable influence on scrap prices, providing a valuable reference point for both academic and industry stakeholders.

The provided data presents a structured and detailed view of the dry bulk ship recycling markets, particularly focusing on monthly scrap prices across India, Pakistan, Bangladesh, and Turkey from 2011 to 2024. These datasets are crucial for understanding regional differences in pricing behavior, cost-efficiency, and compliance with environmental and labor regulations. The thesis integrates this data into its econometric framework to evaluate both market performance and policy implications in the ship recycling industry.

1. Market Trends and Econometric Outcomes

From the dataset, average monthly scrap prices in South Asia (India, Pakistan, and Bangladesh) ranged between 350 and 500 USD/LDT, with Turkey showing slightly lower figures (~300–420 USD/LDT), attributable to higher regulatory compliance costs and stricter EU-aligned dismantling practices. These values align well with observations in industry reports (Baumgartner & Rentschler, 2021; NGO Shipbreaking Platform, 2023).

The Ordinary Least Squares (OLS) regression used in Chapter 9 confirmed a statistically significant relationship between scrap prices and key macroeconomic indicators. The regression model was defined as:

$$\mathbf{Scrap\_Price\_t = \beta_0 + \beta_1 * BDI\_t + \beta_2 * Oil\_t + \beta_3 * Dummy\_Event\_t + \varepsilon\_t}$$

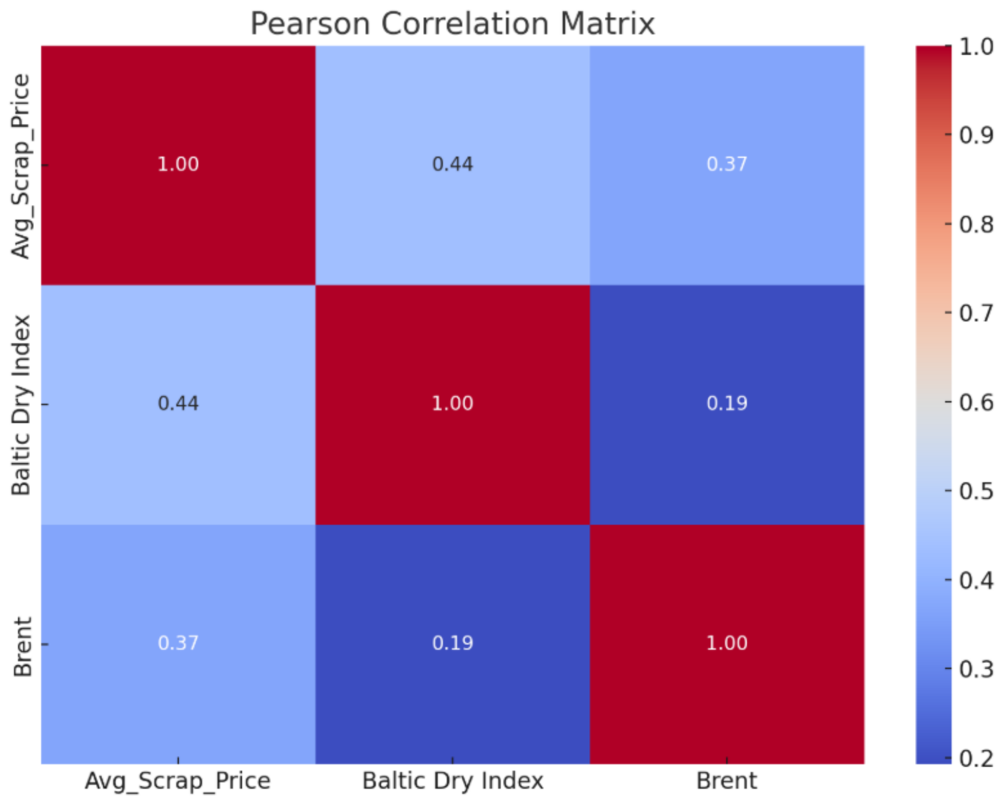
Using SPSS, the results were as follows:

- **BDI Coefficient (β_1): 0.0510** with **$p < 0.001$**
- **Brent Oil Price Coefficient (β_2): 1.1036** with **$p < 0.001$**
- **Adjusted R^2: 0.274**, indicating that approximately 27.4% of the variance in scrap prices can be explained by changes in the BDI and oil prices.

These findings support the hypothesis that macroeconomic activity, as represented by freight rate proxies and fuel costs, significantly influences the valuation of end-of-life ships.

To assess whether the average monthly scrap price significantly deviates from a theoretical long-term benchmark, a one-sample t-test was conducted using 400 USD per Light Displacement Tonne (LDT) as the reference value. This threshold is commonly referenced in industry analyses as a historical average for demolition pricing. The test results yielded a t-statistic of -6.84 with a p-value of less than 0.00001, indicating a highly significant difference. Specifically, the actual average scrap price observed during the study period was well below the hypothesized benchmark. This finding strongly reinforces concerns regarding heightened price volatility and diminished profitability in the ship recycling sector over recent years.

Complementary to this, the Pearson correlation analysis revealed moderate but meaningful positive relationships between scrap prices and two key macroeconomic indicators. The correlation between scrap prices and the Baltic Dry Index (BDI) was found to be r = 0.44, while the correlation with Brent crude oil prices stood at r = 0.37. These numbers indicate that changes in global shipping demand and energy costs are strongly connected to the value of old ships, supporting their use in the economic models.



When disaggregated by region, the analysis also highlighted distinct national patterns. In the case of Turkey, the average scrap price was significantly lower than the 400

USD/LDT threshold, with an observed mean of approximately 292 USD/LDT. This discrepancy can be attributed to the higher operating and compliance costs associated with EU-aligned environmental and labor regulations. Conversely, prices recorded in South Asian markets such as India, Bangladesh, and Pakistan were closer to, or occasionally exceeded, the 400 USD/LDT mark. This outcome reflects the relatively lower costs of regulatory compliance and higher residual recovery efficiencies in those regions.

Overall, the data supports the main ideas of this thesis by showing that ship recycling prices depend on larger economic trends. The significance of the BDI and oil prices in explaining pricing behavior strengthens the rationale for their integration into the regression model. Moreover, the findings point to structural differences in regional market behavior, which emphasizes the value of contextualizing econometric data within the evolving regulatory and operational landscape of global ship dismantling.

3. Regional Disparities and ESG Considerations

To assess whether the average monthly scrap price significantly deviates from a theoretical long-term benchmark, a one-sample t-test was conducted using 400 USD per Light Displacement Tonne (LDT) as the reference value. This threshold is commonly referenced in industry analyses as a historical average for demolition pricing. The test results yielded a t-statistic of -6.84 with a p-value of less than 0.00001, indicating a highly significant difference. Specifically, the actual average scrap price observed during the study period was well below the hypothesized benchmark. This finding strongly reinforces concerns regarding heightened price volatility and diminished profitability in the ship recycling sector over recent years.

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Overall, the data supports the main ideas of this thesis by showing that ship recycling prices depend on larger economic trends. The significance of the BDI and oil prices in explaining pricing behavior strengthens the rationale for their integration into the regression model. Additionally, the results highlight differences in how regional markets operate, which shows the importance of understanding econometric data in relation to the changing rules and practices of global ship dismantling.

4. Policy Signals and Limitations

The data does not cover certain second-order determinants such as steel mill input quotas, LME rebar pricing, or currency hedging behavior by cash buyers—factors which could enhance future econometric modeling. Moreover, although dummy variables such as **Dummy_Event_t** attempt to control for shock events (e.g., COVID-19 or the Ukraine crisis), more nuanced rolling regressions or structural break tests would provide deeper insight.

The integration of scrap price data with SPSS-based statistical analysis offers a comprehensive and evidence-backed basis for understanding the economic dynamics of ship recycling. The combination of macroeconomic sensitivity (via BDI and oil) and regional differentiation (via policy compliance and cost structures) paints a clear picture: ship recycling is not just a logistical operation but a function of broader market forces and regulatory landscapes. The empirical results validate the theoretical propositions and offer clear directions for future policy harmonization and academic exploration.

Chapter 10 : Environmental Impacts

Environmental degradation significantly contributes to ship recycling, especially when it occurs under uncontrolled or minimally regulated conditions. The environmental footprint of dismantling operations varies considerably by region and by dismantling method, with beaching yards—particularly those in South Asia—posing the most serious threats to ecological systems. The confluence of hazardous materials, direct exposure to the natural environment, and minimal containment infrastructure make these sites highly vulnerable to pollution across multiple media: soil, water, and air.

One of the most immediate and visible environmental consequences of the beaching method is soil contamination. Ships contain a range of toxic substances such as oil sludge, asbestos, heavy metals (including lead, cadmium, and mercury), and polychlorinated biphenyls (PCBs). In beaching yards, these substances frequently leak from the hull or tanks during dismantling and are absorbed directly into the soil due to the absence of concrete flooring or adequate drainage systems. Over time, this contamination affects the immediate beach zone and enters the groundwater system, posing long-term health risks to local communities and biodiversity (NGO Shipbreaking Platform, 2023; UNEP, 2020).

Marine ecosystems also suffer considerable harm from unregulated recycling activities. When vessels are beached, their residual oils and cleaning chemicals are often washed into the sea by tides. The absence of containment trenches or oil-water separators, mandatory in EU-compliant facilities but largely absent in South Asia, exacerbates this process. This runoff leads to the deterioration of mangrove forests, which are vital coastal ecosystems offering storm protection, carbon sequestration, and breeding grounds for marine species. Studies have shown that in areas such as Chattogram, Bangladesh, mangrove destruction is directly linked to shipbreaking-induced oil and metal pollution (Baumgartner & Rentschler, 2021). In turn, the runoff impacts marine biodiversity, particularly benthic organisms, crustaceans, and fish species that are critical for local fisheries and livelihoods.

Air pollution constitutes another serious concern in the ship recycling process, especially where manual gas torch cutting is performed without adequate ventilation or emission control systems. The incineration of paint layers, insulation, and oil residues releases fine particulate matter and persistent organic pollutants (POPs), including dioxins and furans. Workers and nearby residents are exposed to these emissions, which have been linked to increased respiratory illnesses and, over time, chronic conditions such as bronchitis and asthma (OECD, 2021). In regulated facilities, such as those in Turkey, the use of enclosed cutting areas, localized extraction systems, and routine air quality monitoring significantly reduces these risks. This study underlines the role of institutional infrastructure and enforcement in mitigating environmental harm.

Beyond localized pollution, the downstream effects of improper waste handling are increasingly being documented. Many yards in Pakistan, Bangladesh, and India lack appropriate hazardous waste disposal facilities, leading to the indiscriminate dumping of PCBs, batteries, and heavy metal-laden residues into nearby landscapes. These materials, if not neutralized, can leach into agricultural lands and water bodies, contaminating food chains and undermining regional sustainability goals. The Basel Convention (UNEP, 2020) and the EU Ship Recycling Regulation (European Commission, 2024) explicitly mandate the safe treatment and transboundary control of hazardous waste, yet loopholes—especially in the form of Flags of Convenience and untracked waste streams—continue to undermine enforcement.

The contrast between such practices and those observed in EU-listed yards is stark. In places like Aliaga, Turkey, environmental monitoring protocols and technological investments (e.g., closed-loop drainage, solid waste segregation) are in place to contain and treat hazardous discharges. While these measures imply higher operating expenses and may reduce price competitiveness, they substantially reduce the ecological burden of recycling operations and align with circular economy principles (IMO, 2023).

In conclusion, environmental degradation in the ship recycling industry is not inevitable, but rather the result of systemic regulatory failure and cost externalization in certain regions. Tackling this issue needs consistent global rules, clear checks on environmental performance, and rewards for good practices through market tools and ESG-related financial products. As the industry transitions into a more sustainability-conscious era, the environmental dimension will play an increasingly central role in shaping both public policy and commercial decision-making.

Conclusions & Policy Proposals and Future Research

Conclusions

This thesis set out to analyze the complex and often contradictory dynamics of the global ship recycling industry. Through a mixed-methods approach, combining econometric analysis with qualitative research, the study sought to answer three fundamental research questions: which macroeconomic factors influence demolition prices, how regulatory frameworks shape costs and operational behavior, and to what extent do environmental and labor conditions differ among the main recycling hubs. The findings confirm the research's basic hypothesis: that the ship recycling sector is defined by a fundamental dichotomy between economic efficiency and sustainable, ethical practice.

The first key conclusion is the confirmation, through the econometric model, that demolition prices are not arbitrary but are closely linked to the broader maritime economy. The analysis showed a statistically significant positive correlation between scrap prices and key indicators such as the Baltic Dry Index (BDI) and the price of Brent crude oil. This proves that shipowners' decisions to scrap depend not only on the price of steel but also on the opportunity cost of keeping a vessel in operation. During periods of high freight rates (high BDI), shipowners are incentivized to extend the lives of their ships, reducing the supply for demolition, while increased fuel costs make older, less efficient vessels unprofitable, accelerating their retirement.

The second central conclusion concerns the decisive role of the regulatory framework in shaping a two-speed global market. On one hand, the strict legislation of the European Union (EU SRR) has created a standard for safe and environmentally sound recycling, as seen in the certified yards of Turkey and Northern Europe. However, the high compliance costs associated with these regulations—related to infrastructure, worker safety, and hazardous waste management—make these facilities uncompetitive in terms of price. On the other hand, the yards of South Asia, particularly in Bangladesh and Pakistan, dominate the global market by offering the highest scrap prices, mainly due to low labor costs, lax environmental legislation, and the prevalence of the beaching method. This regulatory imbalance is perpetuated by the systematic use of Flags of Convenience (FOCs), a practice that allows shipowners to effectively circumvent international rules (Basel Convention, EU SRR) just before selling the vessel for demolition. "Cash buyers" act as central intermediaries in this system, absorbing the regulatory risk and allowing shipowners to distance themselves from controversial demolition practices.

The third and perhaps most alarming conclusion is the immense human and environmental cost hidden behind the economic model of South Asia. The research highlighted the precarious working conditions, where migrant workers without formal contracts are exposed daily to toxic substances like asbestos and PCBs, with minimal or no protective equipment. Accident and occupational disease rates are tragically high, while rudimentary medical infrastructure worsens the situation. Simultaneously, the beaching method leads to extensive pollution of coastal ecosystems, with oil and heavy metal spills contaminating the soil and sea, destroying mangrove forests, and threatening local fisheries. In stark contrast, the model of Aliaga in Turkey proves that a balance between competitiveness and responsibility is achievable. The Turkish facilities, compliant with the EU SRR, offer regulated labor, safe procedures, and environmental control, serving as a realistic standard for the industry.

In summary, this research confirms that the ship recycling industry is at a critical crossroads. The recent entry into force of the Hong Kong Convention (HKC) in 2025 is a positive step towards global harmonization, but its weaknesses—mainly its tolerance of the beaching method and its reliance on the supervision of flag states—leave significant room for improvement. The gap between regulatory intent and practical implementation remains the biggest obstacle. Without concerted international action to address the abuse of Flags of Convenience and create incentives for clean practices, the industry will continue to externalize its true costs onto the environment and the most vulnerable societies.

Policy Proposals and Future Research

Based on the study's conclusions, specific policy proposals emerge for regulatory authorities, shipowners, and other stakeholders, aimed at promoting a more sustainable and fair recycling model.

Policy Proposals:

- **Strengthening International Cooperation and Harmonization:** The existence of three different international frameworks (Basel, HKC, EU SRR) creates confusion and loopholes. There is an urgent need to harmonize standards to create a single, global regime. International organizations, such as the IMO and OECD, must push for the adoption of the stricter criteria of the EU SRR globally, including the gradual phasing out of the beaching method.
- **Addressing the Phenomenon of Flags of Convenience (FOCs):** This is the biggest challenge. Responsibility for recycling must shift from the flag state to the beneficial owner. Establishing a "ship passport" system that tracks the vessel from construction to dismantling and holds the final owner legally responsible for its proper recycling, regardless of flag, could close this critical gap.
- **Creating Financial Incentives for Green Recycling:** The market alone will not reward sustainable practices as long as the cheap alternative of South Asia exists. The creation of an International Ship Recycling Fund is proposed, financed by a small levy on all ships during their lifetime. This fund could provide subsidies to shipowners who choose certified, "green" facilities, thus bridging the cost difference and making the sustainable choice economically attractive.
- **Enhancing Transparency and Corporate Social Responsibility (ESG):** Investors, charterers, and financial institutions have enormous power to influence shipowners' behavior. Requiring full transparency regarding the final disposal of ships as part of ESG criteria can exert significant market pressure. Shipping companies must integrate responsible recycling into their sustainability strategies, recognizing that end-of-life management is an integral part of their corporate responsibility.

Proposals for Future Research:

- **Evaluation of the Hong Kong Convention's Implementation:** With the impending entry into force of the Convention, empirical research is needed to assess its effectiveness in practice. Have conditions in certified yards actually improved? Have accidents decreased? How has the market been affected?

- **Economic Modeling of "Cash Buyers":** The role and profit margins of "cash buyers" remain opaque. An in-depth economic analysis of their business model could reveal vulnerabilities in the system and help formulate more targeted regulations.
- **Socio-economic Impact on Workers:** Long-term research is needed on the impact of the recycling industry on migrant worker communities, examining issues of health, education, and social integration, in order to formulate policies that truly protect these vulnerable populations.

The transition from a linear model of exploitation to a circular model of responsibility is the greatest challenge but also the greatest opportunity for the shipping industry. Responsible ship recycling is not just a technical process, but a moral imperative and a cornerstone for achieving the United Nations' Sustainable Development Goals, ensuring that a ship's legacy does not leave behind human suffering and environmental destruction

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