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Green shipping corridors: a comprehensive framework for overcoming port challenge

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DISSERTATION

GREEN SHIPPING CORRIDORS: A COMPREHENSIVE FRAMEWORK FOR OVERCOMING PORT CHALLENGES

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

(Signature): 

(Date): 15 September 2023

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Abstract

Title of Dissertation: **Green Shipping Corridors: A Comprehensive Framework for Overcoming Port Challenges**

Degree: **Master of Science**

Green Shipping Corridors are seen as a solution to climate change in the maritime industry. However, different stakeholders face unique challenges in implementing these corridors. This dissertation aims to identify barriers and challenges that ports encounter in becoming part of green shipping corridors by conducting interviews with various stakeholders involved in green shipping corridors to get a holistic view of these port challenges. Through these interviews, the study explores ports' drivers and challenges, such as outdated infrastructure, complex regulations, financial concerns, alternative fuel limitations, stakeholder involvement and technological limitations. Based on the insights from these interviews, the dissertation proposes a practical framework to address and overcome these challenges. This framework emphasises stakeholder cooperation and integrating sustainable practices into port engagement in green shipping corridors.

In conclusion, this research emphasises the significance of addressing port challenges in the context of green shipping corridors. As global efforts to make shipping more environmentally friendly, this study also guides ports, policymakers, and industry players by offering a roadmap to help ports overcome these challenges and become active participants in sustainable shipping corridors, ultimately contributing to a greener maritime industry.

KEYWORDS: Green Shipping Corridors, Decarbonization, Port Barriers, Framework, Stakeholders.

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List of Abbreviations

ABS	American Bureau of Shipping
BHP	Broken Hill Proprietary
CII	Carbon Intensity Indicator
Co2	Carbon Dioxide
COP	Confrernce of the Parties
DNV	Det Norske Veritas
EU	European Union
FPV	Future-Proof Vessels
GHG	Greenhouse Gas
GMF	Global Maritime Forum
HI-FIVED	Hydrogen Innovation – Future Infrastructure & Vessel Evaluation and Demonstration
IAPH	International Association of Ports and Harbours
IMO	International Maritime Organisation
LBTS	Land-based Test Sites
LR MDH	Lloyd's Register Maritime Decarbonisation Hub
MTCC	Maritime Technology Cooperation Centre
MMMC	The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping
MEPC	Maritime Environment Protection Committee
MoU	Memorandum of Understanding
MPA	Maritime and Port Authority of Singapore
NGO	Non-governmental Organisations
OECD	Organisation for Economic Co-operation and development
OPS	Onshore Power Supply
PIL	Pacific International Lines
POLA	Port of Los Angeles
POLB	Port of Long Beach
Q-CHAMP	QUAD Climate Change Adaptation and Mitigation Package
RMC	Rauma Marine Constructions
SIDS	Small Island Developing States
UK	United Kingdom
UNFCCC	United Nations Climate Change Conference
US	United States
WMU	World Maritime University
WSC	World Shipping Council

1. Chapter 1: Introduction

1.1 Background

Climate change is one of humanity's most significant global challenges today, and reducing Greenhouse Gas (GHG) emissions is a crucial step in addressing this issue. Human activities, notably the burning of fossil fuels and deforestation, have increased atmospheric concentrations of GHGs, causing the Earth's average surface temperature to increase. This leads to a wide range of negative impacts, including rising sea levels, more frequent and intense heatwaves, droughts, and storms, as well as damage to ecosystems and loss of biodiversity (United Nations, 2023). Individuals, governments and organisations must work together to reduce GHG emissions, adopt sustainable practices and transition to a low-carbon economy to ensure a stable and healthy planet for future generations.

Indeed, studies have provided compelling evidence that human-caused increases in heat waves have significant economic impacts, particularly affecting weak regions in the tropics that have contributed the least to global warming. The cumulative losses from anthropogenic extreme heat during the period from 1992 to 2013 are estimated to be substantial, ranging from $5 trillion to $29.3 trillion on a global scale (Callahan & Mankin, 2022). These staggering figures unequivocally demonstrate the adverse consequences of climate change on various aspects of our lives.

The International Maritime Organisation (IMO) has been actively committed to reducing GHG emissions from the shipping industry and advancing its decarbonisation efforts. In 2011, the IMO adopted its first internationally mandated standards to enhance ship energy efficiency (IMO, 2011). Subsequently, in 2018,

the IMO introduced an initial GHG strategy, outlining comprehensive short-, medium-, and long-term policy strategies to attain emission reduction goals. Over the years, the IMO has set ambitious targets for decreasing GHG emissions and has established regulations to enhance the energy efficiency of ships during their construction, development, and operation (IMO, 2023a). The latest revision of the GHG Strategy in 2023 reflects a heightened common ambition to achieve net-zero GHG emissions from global shipping by around 2050. The commitment also includes ensuring the uptake of alternative zero and near-zero GHG fuels by 2030 and indicative checkpoints for 2030 and 2040 (IMO, 2023b).

The IMO encourages data collection and reporting on GHG emissions from international shipping, fostering transparency and enabling effective monitoring of progress towards the set targets (Sun et al., 2022). These strategies aim to position the shipping sector as a crucial contributor to fulfilling the objectives of the Paris Agreement and facilitating the global transition toward a sustainable and low-carbon future (Joung et al., 2020).

Moreover, several unilateral actions have been stalled by different countries; for example, The Green Deal is the EU's (European Union) response to the climate crisis, committing to legally binding goals of 55% emission reduction by 2030 and achieving climate neutrality by 2050 (European Parliament, 2023). In addition, the EU agreed to include shipping in its Emission Trading System (EU ETS) and cargo and passenger vessels, their gross tonnage of more than 5000 GT used for commercial purposes in the EU, will be required to acquire and surrender emission allowances for carbon dioxide (CO2) emissions beginning in 2024, with offshore ships starting in 2027 (DNV, 2023a).

In this context, green shipping corridors have emerged as a strategic approach to promote low- and zero-carbon maritime transportation solutions along major shipping routes. A green corridor integrates alternative fuel production, transport,

and bunkering ports to serve a substantial share of global marine fuel demand efficiently. (H. Wang et al., 2023).

While green corridors hold immense potential to drive decarbonisation efforts, it is crucial to prioritise the decarbonisation goal in these projects. Emphasis should be placed on creating a well-coordinated, inclusive, and evenly distributed network of green ports (Hubatova, 2022). Such an approach will not only support shipping's transition to a low-carbon future but also ensure the thriving of communities and the protection of the environment.

1.2 Problem Statement

The shipping industry significantly supports the global economy and plays a crucial role in international trade and commerce by transporting goods and products worldwide. However, shipping is often viewed as an extra cost to the goods being transported, and cargo owners tend to look for the most cost-effective way to transfer their cargo, regardless of the environmental impact. This can lead to challenges for the shipping industry in balancing cost-effectiveness with environmental sustainability.

A green shipping corridor offers a promising solution for the shipping industry to address GHG emissions effectively. The key strength of the green corridors lies in their ability to promote collaboration among all stakeholders in the shipping sector, enabling them to collectively tackle environmental challenges and work towards achieving the targets set by the IMO (DNV, 2023b).

In addition, green shipping corridors necessitate significant investments in infrastructure for low- and Zero-emission fuels. Their total value enhances national and local economic benefits while promoting environmental well-being and community interest. This approach optimises economic improvements through job

creation, trade facilitation, and increased tax revenue, maximising the corridors' overall impact on society and the economy (Arup, 2023).

Despite its potential, implementing a green corridor is challenging. Various limitations are faced by shipping companies, ports, alternative fuel providers, governments, and infrastructure developers, making the task of establishing and maintaining a green corridor complex demanding.

In addition, ensuring the availability and accessibility of alternative fuels can be a daunting task for fuel providers, necessitating new infrastructures and supply chains. As a crucial part of the corridor, ports must adapt and invest in greener infrastructure and services to accommodate vessels powered by alternative fuels (Prussi et al., 2021). Moreover, coordinating and integrating diverse stakeholders across different regions places additional logistical and regulatory challenges.

1.3 Aim and Objectives

This study seeks to propose a comprehensive analysis to enhance the sustainability and environmental friendliness of the shipping industry, concurrently promoting economic growth and competitiveness within the sector. Moreover, it aims to contribute to the IMO 2050 objective of achieving zero-emission solutions for decarbonisation. By identifying the challenges and barriers ports face in becoming part of the green shipping corridor, the study aims to promote a framework that will enable ports to address these challenges effectively. The framework will guide ports to facilitate their integration into the green corridor, supporting adopting sustainable practices and contributing to the sector's ecological goals.

The research embraces three objectives:

1. Identify the benefits of developing a green shipping corridor.
2. Propose solutions to address the port barriers of the green shipping corridor and facilitate international cooperation among stakeholders.

3. Demonstrate key stakeholders' interest in developing Green Shipping Corridors.

1.4 Research Questions

1. What are the benefits of developing a green shipping corridor?
2. What are the port challenges to developing a green corridor, and how can they be addressed?
3. How can international cooperation be facilitated among stakeholders to develop a green shipping corridor?

1.5 Methodology

This research constitutes a thorough literature review that centres on implementing green shipping corridors and the specific challenges confronting ports. While the initial intention was to perform a systematic literature review using diverse databases, the outcomes produced just a few relevant articles. Consequently, the researchers opted for a traditional literature review approach to explore the subject comprehensively.

Semi-structured interview questions were developed based on the insights from the literature review to gain a richer understanding and identify the practical challenges and barriers ports face. These questions were directed at various stakeholders in the shipping industry in implementing the green shipping corridor.

The literature review and the responses obtained through the interviews served as a crucial highlight, providing valuable and first-hand insights into the challenges and obstacles experienced by ports in their efforts to become part of the green shipping corridor. This comprehensive framework for ports to be part of green corridors was formulated from extensive understanding. The framework addresses the identified challenges and provides practical guidance for ports to integrate into the Green Shipping Corridor effectively.

1.6 Key Assumptions and Potential limitation

1. The research study focused solely on the port aspect of the green shipping corridor, limiting the scope of the investigation to this specific area.

2. One of the primary challenges encountered during the research was the limited availability of secondary data sources related to the new and emerging topic of green shipping corridors.

3. Time constraints posed another significant limitation. Conducting a comprehensive investigation on the intended topic requires ample time to collect and analyse data, conduct interviews, and gather information from various stakeholders.

1.7 Research Scope

The role of ports in implementing the green shipping corridor is essential. This research seeks to delve deeply into the specific functions and responsibilities of ports within the framework of the green shipping corridor. It aims to investigate the key role of ports in facilitating the adoption and operation of the green shipping corridor. Additionally, the research will explore the specific requirements that ports need to meet to effectively participate in and contribute to the success of the green shipping corridor.

Furthermore, this dissertation aims to determine and analyse ports' barriers and challenges while attempting to join the green shipping corridor. The study exposes the challenges that prevent ports from adequately integrating into the green corridor by thoroughly investigating these barriers.

1.8 Ethical Issues

The World Maritime University's (WMU) Research and Ethics Committee approved the study, maintaining academic ethics and integrity. The study followed all ethical standards, including getting participants' consent before data collection and protecting individuals' confidentiality and privacy rights.

The third chapter of this research explains the methodological approach and procedures used in the study in context. By offering a detailed overview of the research methodology, this chapter explores the comprehensive specifics of the research methodology, including the rationale behind the selected approach and the techniques used for data collecting, analysis, and interpretation.

1.9 Dissertation Structure

The dissertation is organised into six chapters, as illustrated in Figure (1), each contributing to comprehensively exploring the topic. Chapter One serves as an introduction, providing the research's background, aims, objectives, and research questions. Building on this, Chapter Two delves into an extensive literature review encompassing green shipping corridor topics, their development dynamics, Memorandums of Understanding (MoU), the core stakeholders involved, and the challenges ports encounter.

Chapter Three elaborates on the research methodology and the employed data collection techniques, followed by a detailed data analysis in Chapter Four. This analysis is centred on the outcomes of semi-structured interviews, scripted and coded, alongside a comprehensive discussion of the diverse perspectives expressed by stakeholders. Chapter Five's practical framework arises, offering a roadmap for port engagement within green shipping corridors. This framework encapsulates steps for enhancing awareness, identifying and addressing port-specific barriers, developing collaborations, and strategically integrating new technologies.

Lastly, Chapter Six provides the dissertation's conclusive insights, consolidating the findings and their implications. Additionally, it suggests future research directions, ensuring the study's contribution remains a springboard for further inquiry in the field.

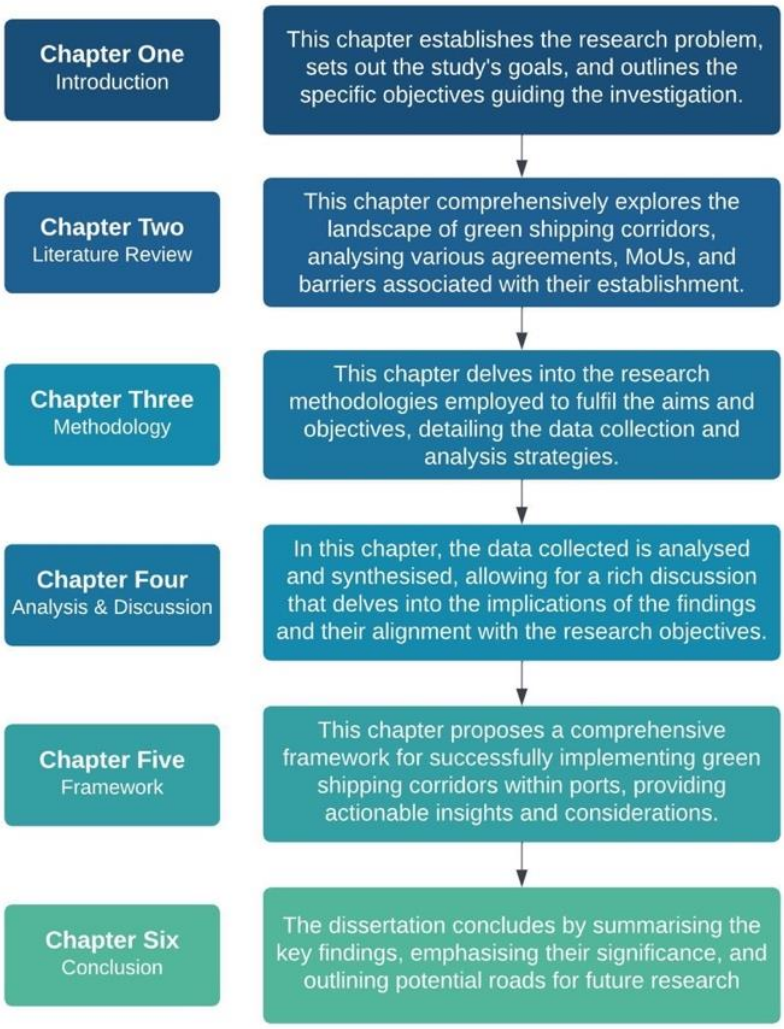

Figure 1 Dissertation structure

2. Chapter 2: Literature Review

2.1 Introduction

Chapter two provides a comprehensive literature review focusing on the inception and progression of the green shipping corridor concept and all its corners. It investigates the various routes associated with these environmentally conscious transportation corridors. It explores the starting of the green shipping corridor concept, its definitions, the existing MoU between the port and the challenges of ports and alternative fuel, and a proposed sustainable energy source for these corridors.

By analysing these key components, this review establishes a solid understanding of the evolution of the green shipping corridor concept and the influential factors shaping its implementation. Furthermore, understanding the relationship between ports, alternative fuels, and the establishment of green corridors is crucial for policymakers, industry stakeholders, and researchers seeking to promote eco-friendly practices within the shipping industry.

2.2 Green Shipping Corridor Definitions

Green shipping corridors have gained significant attention recently as a crucial step towards decarbonisation and a mid-term strategy to achieve the IMO target. Various organisations and classification societies in the maritime industry have extensively studied and defined the concept of green corridors.

The Global Maritime Forum (GMF) and its collaborators outlined a fundamental definition of a green shipping corridor as "*A shipping route between two major port hubs (including intermediary stopovers) on which the technological,*

economic, and regulatory feasibility of the operation of zero-emissions ships is catalysed through public and private actions" (GMF, 2021). Different entities within the sector have widely accepted and adopted this definition, for instance, C40 Cites and DNV (C40, 2023; DNV, 2023a).

In the United States (US), green corridors are envisioned as "*Maritime routes that showcase low- and zero-emission lifecycle fuels and technologies with the ambition to achieve zero GHG emissions across all aspects of the corridor in support of sector-wide decarbonisation no later than 2050*" (US GOV, 2022a). This vision aims to shift the focus from just zero-emission corridors to encompassing zero- and low-emission corridors.

The American Bureau of Shipping (ABS) provided a comprehensive definition by dividing the concept into two components. Firstly, "*Green indicates that the foundational focus of the Corridor is on emission reduction",* aligning with the US government's definition of both low- and zero-carbon maritime routes. Secondly, "*Corridor refers to the geographical connection between two locations, involving specific maritime routes or multiple ports between two regions*" (ABS, 2022).

Furthermore, The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMC) defines green corridors as shipping routes where commercially operating ships use exclusively alternative fuels (MMMC, 2022a). Additionally, the MMMC distinguishes the Corridor into three types: "Single Point" establishes a zero-emission shipping route centred on a specific location, such as port hubs, enabling round-trip bunkering; "Point to Point" signifies routes between two ports; and "Network" involves establishing routes between three or more ports where vessels can navigate on zero-emission fuel, as shown in Figure (2) (MMMC, 2022a).

These various definitions and classifications of green shipping corridors underscore the global shift toward decarbonising the maritime industry.

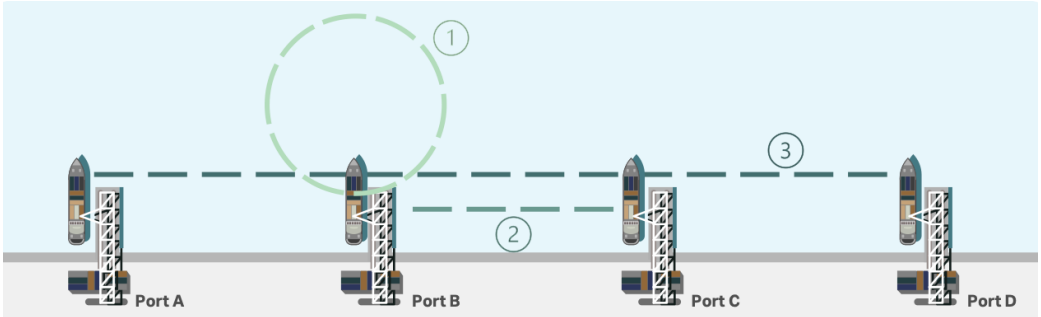

Figure 2 Green Shipping Corridor Types, Source: (MMMC, 2022a)

Moreover, green corridors seek to engage various participants within the value chain to overcome challenges to adopting alternative fuels. It is essential to identify stakeholders involved in the green corridor and understand their respective roles. By doing so, this initiative can offer a strategic framework and blueprint for stakeholders to enhance their confidence and embark on an expeditious pathway toward decarbonisation.

Considerable stakeholders participate in the green corridor, their specific involvement contingent upon the characteristics of the corridor itself. Nevertheless, as shown in Figure (3), the primary stakeholders in the green corridor encompass ports, fuel production industries, ship owners/operators, cargo owners, the end consumer, and entities involved in Financing and regulation, such as governments (ABS, 2022; MMMC, 2022a). Each stakeholder plays a crucial role in attaining the objectives of the green corridor.

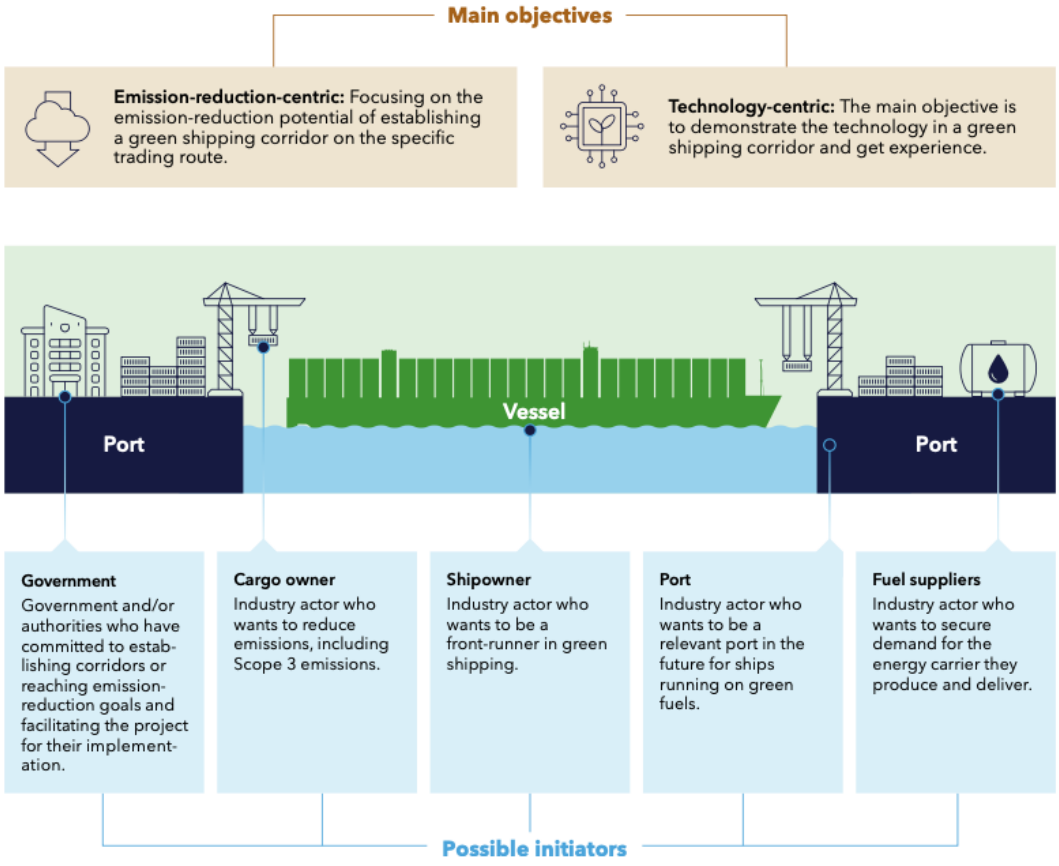

Figure 3 Main objectives and stakeholders of green shipping corridor, Source: (DNV, 2023a)

While the development of each green corridor is likely to be unique and influenced by various factors, there is a general outline of steps that can be followed in the establishment process. The initial step involves the initiation phase, during which announcements are made, As illustrated in Figure (4), initial partnerships are formed, and preliminary assessments are conducted to gauge the feasibility of potential routes. However, it should be noted that these initial steps may sometimes be a fixed sequence in every scenario of developing a green corridor (GMF, 2022).

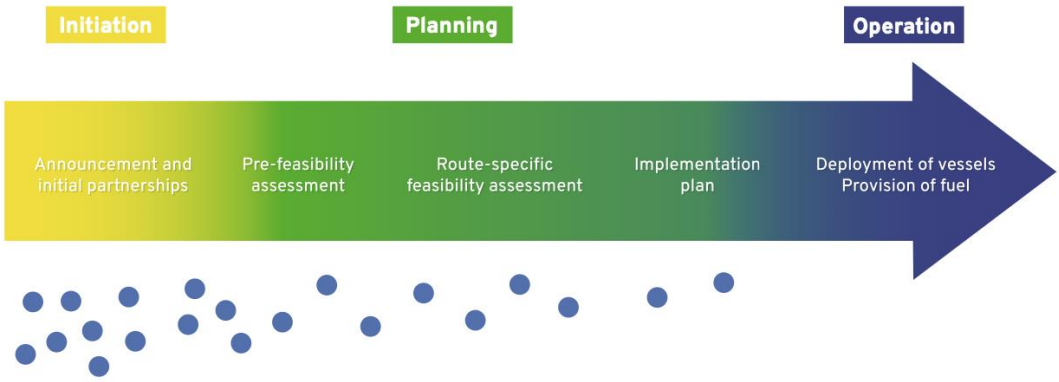

Figure 4 Green Shipping Corridors Initiation Phases, Source:(GMF, 2022)

Subsequently, the planning phase comes into play, where a detailed evaluation is undertaken, explicitly focusing on the technical and economic viability of each route identified for the green corridor (GMF, 2022). The planning stage culminates with formulating an implementation plan or a comprehensive route map, presenting a strategic course of action for successfully realising the green corridor.

Once the planning phase is completed, the green corridor proceeds into the operational phase. This critical stage involves the practical deployment of vessels with green technologies, prioritising zero-emission capabilities. During this operational phase, an essential milestone is reached as scalable zero-emission fuels are made available to power the vessels (GMF, 2022).

2.3 Developing of Green Shipping Corridor Concept

This literature review explores the concept of green corridors across different types of transportation, including water, air, rail, and road. For instance, the EU introduced a green corridor concept in 2007, aiming to develop integrated, efficient, and environmentally friendly freight transportation over long distances between major hubs (Psaraftis & Panagakos, 2012). Moreover, the Swedish government initiated the Green Corridors project in 2010, focusing on establishing green corridors from and to Sweden and the Nordic region (Trafikverket, 2014).

Nevertheless, this review focuses explicitly on green shipping corridors, which gained momentum at the 2021 United Nations Climate Change Conference (UNFCCC), Conference of the Parties (COP) 26 in Glasgow when the Clydebank Declaration was formally ratified by a consortium of 24 governmental bodies, signifying a pivotal moment in cooperation and political commitment (Peneueta, 2023).

The collaborative goal of the Clydebank Declaration is to support the establishment of at least six green corridors between 2025 and 2027. Furthermore, aspirations encompass expanding these initiatives in the next years, which entails supporting the establishment of additional routes, extending their length, and enhancing efficiency by increasing the number of vessels operating along these routes (GOV UK, 2022a).

During the 27th Conference of COP in Sharm El Sheikh, Egypt, the 24 governments that have approved the Clydebank Declaration are celebrating its first anniversary. This event serves as an opportunity to assess the advancements made thus far, including reviews on the annual progress report on green shipping corridors, which the GMF is releasing in collaboration with the getting to zero coalition (Fahnestock, 2022).

Through the 78th session of the Marine Environment Protection Committee (MEPC), the World Shipping Council (WSC) presented a document (MEPC 78/7) in February 2022 endorsing the implementation of green shipping corridors. The WSC emphasised that green corridors have the potential to address challenges faced by liner shipping companies and can serve as pioneers in adopting low- and zero-GHG ships. Furthermore, the WSC described green corridors to facilitate the transition of fuels and technologies in the maritime sector. They also highlighted the practicality of green corridors as a mechanism for the IMO, Member States,

and stakeholders to channel investments that promote compliance with specific regulations. The WSC proposed that green corridors should be essential to the expanded IMO GHG strategy (IMO, 2022a).

In addition to the WSC, the United States (US) submitted a document (MEPC 78/7/24) expressing support for the green shipping corridor (IMO, 2022b). Japan also acknowledged the role of green corridors in its document (MEPC 78/INF.7) submitted to the MEPC 78th (IMO, 2022c). Moreover, Denmark, Norway, Singapore, and the US jointly submitted a document (MEPC 78/INF.14) in March 2022 to the MEPC 78th session, highlighting that green corridors would facilitate comprehensive testing of zero-carbon shipping throughout the entire value chain (IMO, 2022d).

During the 79th MEPC session, WSC submitted a document (MEPC 79/7) highlighting the potential of green corridors to connect developed and developing countries' economies. They proposed the introduction of suitable vessels and fuel infrastructure to provide specific routes, with a gradual expansion of the served routes. (IMO, 2022e).

Moreover, Australia, Canada, Jamaica, Kenya, Morocco, Norway, Singapore, the United Kingdome (UK), the International Association of Ports and Harbours (IAPH), and the WSC jointly submitted a document (MEPC 79/7/14) advocating for the development of route-based actions in the form of green shipping corridors. They highlighted that several member states have initiated collaborative efforts through MOUs to develop green corridors. These corridors would serve as platforms for demonstrating and testing low- and zero-emission technologies and fuels while also identifying opportunities and challenges in their implementation (IMO, 2022f).

Furthermore, Norway, the Republic of Korea, and the WSC jointly presented a document (MEPC 79/7/17) discussing how green corridors can facilitate the transition toward a decarbonised maritime sector. They highlighted the importance of the organisation's active involvement in progressing green corridors, emphasising the potential for safer, more inclusive, and harmonised development. In addition, they stressed the need for a clear definition of the term "Green Shipping Corridor" (IMO, 2022g).

During the 80th session of the MEPC, several documents were submitted by various organisations and countries, expressing their support and perspectives on the concept of green corridors. One document (MEPC 80/7/2) was submitted by IAPH, which stated that IAPH has backed the idea of green corridors since its inception. However, the organisation also emphasised the importance of ensuring that green corridors are not only perceived as promotional initiatives but are genuinely well-intended pioneering projects addressing environmental concerns in the maritime industry (IMO, 2023c).

Additionally, the Organisation for Economic Co-operation and Development (OECD) presented a document (MEPC 80/INF.12) expressing its support for green shipping corridors and highlighting their potential to accelerate the adoption of e-fuels (IMO, 2023d).

Moreover, the Republic of Korea also submitted a document (MEPC 80/INF.27) emphasising the importance of establishing land-based Test Sites (LBTS) to promote voluntary port-to-ship cooperation initiatives within green corridors. These initiatives encompass carbon-free fuel production, bunkering infrastructure development, and the demonstration of low or zero-carbon fuel ships (IMO, 2023e).

Furthermore, a document (MEPC 80/INF.39/Add.1) submitted by the Secretariat suggested the inclusion of green corridors in the revised IMO GHG strategy. The document emphasised the necessity for improved technical assistance to implement the revised strategy successfully. (IMO, 2023f).

2.4 Green Corridors Memorandum of Understanding (MoU) and Projects

Following the Clydebank Declaration at COP 26, several governments embarked on the path of collaboration by signing MOUs or projects to achieve their environmental targets.

2.4.1 Singapore - Rotterdam Green Corridor

The first notable example is the Maritime and Port Authority of Singapore (MPA) and the Port of Rotterdam collaboration. These ports, which serve as major global bunkering hubs (Bunkerpay, 2023), have established an MOU to develop the longest green and digital shipping corridor. This corridor facilitates low and zero-carbon shipping along the Asian-European shipping lanes. The ports intend to provide sustainable alternatives, including biofuels and ongoing research and development on synthetic methane, hydrogen, ammonia, and methanol. The MoU also emphasises optimising maritime efficiency, safety, and the seamless flow of cargo by sharing relevant data, electronic documentation, and standards (MPA, 2022; Port of Rotterdam, 2022b).

2.4.2 Singapore - Los Angeles - Long Beach Green Corridor

In addition, the MPA, Port of Los Angeles (POLA), and Port of Long Beach (POLB) have joined forces, supported by C40 Cities, to establish a green and digital shipping corridor that supports decarbonisation in the maritime industry. These ports, crucial nodes along the trans-Pacific shipping lane, aim to facilitate the transition to low and zero-emission fuels for ships calling Singapore and the San Pedro Bay port complex. (MPA, 2023a; POLA, 2023a; POLB, 2023).

2.4.3 Singapore - Australia Green Corridor

Moreover, MPA and Australia have collaborated significantly, culminating in the green and digital shipping agreement signed in October 2022. As part of this cooperative endeavour, both countries have committed to establishing the Singapore-Australia green and digital shipping corridor by the end of 2025 (Australian Government, 2022).

2.4.4 The Silk Alliance

Furthermore, the Lloyd's Register Maritime Decarbonisation Hub (LR MDH) and the MPA have signed an MoU to cooperate on developing a fleet-specific decarbonisation strategy and implementation plan for The Silk Alliance. This collaborative effort, spanning multiple industries, is centred on creating a regional green corridor cluster in Asia to facilitate emissions-free shipping between the Indian and Pacific Oceans. The partnership aims to pilot decarbonisation initiatives tailored to container ships, mainly in the Asian region. (LR, 2023a; MPA, 2023b).

By joining The Silk Alliance, the MPA strengthens its commitment to enhancing collaboration among global maritime industry players and Singapore's port. This initiative engages stakeholders from the private and public sectors throughout the shipping value chain, with initial members listed in Table (1). Initially concentrating on a baseline fleet that primarily refuels in Singapore and navigates across Asia, East Africa, the Middle East, Australia, and the Pacific Islands, The Silk Alliance's implementation phase aims to expand its scope to encompass additional regional hubs and long-haul routes, including the Singapore-Rotterdam corridor. (LR, 2023a; 2023b).

2.4.5 Rotterdam - Gothenburg Green Corridor

In addition to the MoU between the Port of Rotterdam and the MPA mentioned earlier, another collaboration exists between the Port of Rotterdam and the Port of Gothenburg. These ports have signed a MoU to establish a Green Corridor to

promote sustainable shipping between the two ports. This initiative seeks to create a collaborative framework to encourage the utilisation of new alternative fuels, which are essential for achieving full decarbonisation in the maritime sector (Port of Rotterdam, 2022b; The Port of Gothenburg, 2022).

2.4.6 Gothenburg – North Sea Port Green Corridor

The Port of Gothenburg and North Sea Port (Ghent) have collaborated to establish a green shipping corridor, furthering their commitment to sustainable maritime practices. In this joint effort, the two port authorities have set their sights on transforming the designated route into a green corridor, with a targeted completion date of 2025 (North Sea Port, 2022; Talalasova et al., 2022).

2.4.7 European Green Corridors Network

Moreover, the Port of Rotterdam holds the European Green Corridors Network membership. This network was established by the MMMC in close collaboration with the Port of Hamburg, Port of Gdynia, Port of Roenne, Port of Rotterdam, and Port of Tallinn. This initiative aims to demonstrate the early commercialisation of low and zero-fuel supply chains, promote and facilitate innovative solutions, and create a roadmap for expanding green shipping corridors to additional regions and locations.

In addition, this partnership aims to lay the groundwork for the European Green Corridors Network by focusing on establishing green corridors in Northern Europe and the Baltic Sea region during its initial phase (IMO, 2022h; MMMC, 2022b; Port of Rotterdam, 2022c; Port of Tallinn, 2022).

2.4.8 Clean Tyne Corridor

The Clean Tyne Shipping Corridor consortium is committed to advancing the goal of zero-emission shipping and aligning with the objectives of the UK Government's Clean Maritime Plan. As part of this commitment, the consortium is

embarking on a comprehensive feasibility study to establish a green corridor from the UK's northeast coast, specifically the Port of Tyne (Port of Tyne, 2023). The overarching vision is to seamlessly integrate this corridor with the European Green Corridors Network, creating a synergistic and interconnected network of sustainable maritime routes connecting the UK with Europe (GOV UK, 2022b).

Inaugural members include Shown in Table (1) (Newcastle University, 2023). Each member brings their specialised expertise and resources to the table, collectively contributing to this transformative initiative's realisation. To support the project's implementation, the Corridor consortium has successfully secured funding of over £500,000, with a significant contribution of £390,000 from the UK Government (Newcastle University, 2023).

2.4.9 Nordic Green Corridors

Another agreement is to create Nordic green shipping corridors for emission-free shipping. This project, known as the Nordic Roadmap, is centred around establishing a collaborative platform for Nordic Cooperation. The main objectives of this project are to facilitate knowledge sharing, conduct pilot projects, and conduct studies to gain knowledge utilising alternative fuels. Additionally, the project aims to establish green corridors and the necessary enabling infrastructure (Nordic Co-operation, 2022). DNV (Det Norske Veritas) leads this endeavour, which will take on a leadership role in coordinating the efforts of various stakeholders. The project has been granted 1 million Danish Krone in funding (Andersen, 2022).

2.4.10 The Decatrip

In the realm of Nordic cooperation, an additional collaboration between Sweden and Finland is their collaborative commitment to establish a green corridor known as The Decatrip project. This project is a collaborative effort among several entities, Shown in Table (1). The ambitious target is set to be achieved by the year

2027 (PBI, 2023; Port of Turku, 2022). This collaborative project aims to establish a green corridor connecting Stockholm and Turku Ports, enabling the transportation of both cargo and passengers.

The project has received significant support from Business Finland, which has granted 1,596,000 EURO in funding for developing the green shipping corridor. (Abo Akademi, 2022).

2.4.11 United Kingdom – France Green Corridor

A notable collaboration between the UK and France is the Green Shipping Corridor initiative. This joint effort supports the route between the Ports of Calais and Dunkirk and the Port of Dover, facilitating a seamless transition towards green crossings between the UK and France (Port of Dover, 2023).

This project is an extension of the successful Dover Clean Ferry Power Project, which was initially part of the first Clean Maritime Demonstration Competition. The consortium involved in this endeavour is shown in Table (1) (Bruno, 2022).

2.4.12 United Kingdom Green Corridor (HI-FIVED)

The UK has taken a stride by supporting the establishment of a Green Corridor connecting Aberdeen to the Orkney and Shetland Islands. This pioneering project encompasses the development of a green corridor and involves the utilisation of hydrogen-powered autonomous ships for cargo transportation. With a budget of £5.4 million, the project is anticipated to be completed by the autumn of 2024. The initiative, known as the 'Hydrogen Innovation – Future Infrastructure & Vessel Evaluation and Demonstration (HI-FIVED),' is a consortium that will receive more than £3.8 million in funding from the UK government. The primary focus of the funding is to support the construction and demonstration of innovative autonomous vessels and bunkering infrastructure technologies designed to use liquid hydrogen (Port of Aberdeen, 2023).

2.4.13 Spain Green Corridors

Spain actively pursues participation in green corridors by identifying optimistic international routes and promoting stakeholder dialogue. A study in collaboration with the GMF, the Energy Transitions Commission, and the British Embassy in Madrid highlights a significant opportunity for the Spanish economy to engage in green corridors. The study suggests that Spain has specific advantages that position it as a potential leader in this field (Talalasova et al., 2023).

The study identified several short- and deep-sea opportunities for green corridors in Spain, each presenting distinct advantages and challenges regarding impact and feasibility. Among these opportunities, the green corridor between Spain and partner countries such as the UK, Italy, and the US emerged as the most promising. Additionally, the study identified potential collaborations with Turkey, Morocco, and China, thus outlining eight promising green corridors that can serve as critical pathways for sustainable maritime transport (Talalasova et al., 2023).

2.4.14 Antwerp – Montreal Green Corridor

The Port of Antwerp and the Port of Montreal have collaborated to promote the creation of a green corridor in the North Atlantic region, marking a shared commitment by these significant players in transatlantic marine transportation. Through this agreement, they aim to engage their public and private partners in jointly assessing, identifying, developing, and implementing solutions and infrastructure that benefit both parties.

The primary objective is to facilitate the trade of green fuels and provide vessels with renewable fuels and clean technologies (Port of Antwerp Bruges, 2023; Port of Montreal, 2023).

2.4.15 Halifax - Hamburg Green Corridor

Another collaboration between Europe and Canada, the Hamburg Port and the Halifax Port, has signed an MoU to facilitate port infrastructure development for bunkering and exporting green hydrogen and its derivatives. This collaboration aims to foster cooperation among value chain partners, shipping lines, and other stakeholders to accelerate the adoption of green energy along the corridor.

Moreover, the MoU aims to advance renewable hydrogen technologies and support bilateral cooperation between Canada and Germany in expanding the global hydrogen economy (Port of Halifax, 2022).

2.4.16 Great Lakes - St. Lawrence Seaway System

Canada and the US are collaboratively working to create a Green Shipping Corridors Network in the Great Lakes - St. Lawrence Seaway System. This involves governmental bodies, as shown in table (1), along with state, local communities, private-sector entities, non-governmental organisations (NGOs), and Indigenous Peoples from both countries. The initiative includes consultations with ports and other stakeholders to establish the Great Lakes Green Shipping Corridor Network. (Transport Canada, 2022).

2.4.17 Alaska - British Columbia – Washington Green Corridor

As part of the ongoing collaboration between the US and Canada, a joint effort was launched in May 2022, spearheaded by ports, industry stakeholders, governments, and NGOs. The primary objective of this initiative is to investigate the feasibility of establishing a green shipping corridor that will expedite the deployment of zero-emission ships and operations between Alaska, British Columbia, and Washington. Specifically, this collaborative effort aims to create the first cruise-focused green corridor, with major cruise lines operating along the Seattle-Alaska route and making port calls at British Columbia, Juneau, and Vancouver after departing from

Seattle (Port of Seattle, 2022). This route will be powered by an electric Onshore Power Supply (OPS) (AAPA, 2023).

2.4.18 Gulf of Mexico Green Corridor

The Gulf of Mexico green shipping corridor is currently in the developmental phase, aiming to facilitate the efficient flow of cargo along the Intracoastal Waterway and the Lower Mississippi River system, effectively connecting the ports of New Orleans and Houston (Talalasova et al., 2022; US GOV, 2022b). This ambitious project envisions a comprehensive and eco-friendly network.

2.4.19 Los Angeles – Shanghai Green Corridor

In the US, alongside the two green shipping corridors established in collaboration with Canada and one with Singapore, another noteworthy initiative involves the POLA and the Port of Shanghai. These two major ports have announced a ground-breaking partnership through the C40 cities network in conjunction with shipping companies and a network of cargo owners. Their collective effort aims to create the world's first transpacific green shipping corridor, operating along one of the busiest container shipping routes in the world (C40, 2022).

Furthermore, The POLB has also joined the Shanghai-Los Angeles Green Corridor, demonstrating a commitment to support and contribute to the goals of this transformative initiative (POLB, 2022).

2.4.20 US-Japan Green Corridor

Establishing the Green Shipping Corridor MoU marks a significant step in formalising collaboration between the POLA and the Ports of Tokyo and Yokohama to jointly address sustainability and environmental concerns within the maritime industry (POLA, 2023b).

One of the key focus areas under these MoUs is the digitalisation of the supply chain, which is intended to optimise operational efficiency and reduce the environmental impact of port operations. By leveraging digital technologies, the ports aim to enhance their ability to monitor and manage cargo movement, streamlining processes and minimising energy consumption (POLA, 2023b).

2.4.21 US-ROK Green Corridor

During COP27, both the Republic of Korea and the US announced their commitment to technical cooperation to facilitate the establishment of a green shipping corridor. This collaboration focuses on creating a green corridor between the Busan port and the ports of Seattle and Tacoma in the US (US Mission Korea, 2022).

The proposed Busan-Seattle/Tacoma green corridor is considered an ideal complementary addition to the already successful Los Angeles-Shanghai green corridor, which has set a positive precedent for sustainable maritime transportation between regions (Yum, 2023).

2.4.22 Chilean Green Corridor Network

The Chilean Ministries of Energy, Transport and Telecommunications, and Foreign Affairs, in collaboration with the MMMC, have launched a project named the Chilean Green Corridors Network. This project highlights a successful partnership between the public and private sectors, which is crucial for achieving maritime decarbonization and promoting global sustainability efforts. The Chilean Government and Ministries have shown a solid dedication to addressing climate change and have established an ambitious roadmap for decarbonizing Chile and the whole region. (Chilean Ministries of Energy, 2022).

The Chilean Green Corridor holds the potential to embrace various types of alternative fuels, such as hydrogen, ammonia, and methanol, resulting from

renewable power sources. Demonstrations of producing these fuels from renewable energy have already been successful, necessitating a substantial and expeditious scale-up to enable their adoption in the shipping industry (Svendsen et al., 2023).

The implementation of the Chilean Green Corridor will occur in waves. The first wave of the green corridor project will encompass shipping routes between northern Chile and Asia/Europe, including the transportation of ammonia carriers from Chile to Europe/Asia, sulfuric acid transportation from Chile/Peru/Asia to northern Chile, and the use of zero-emission tugboats in Chilean ports (Svendsen et al., 2023).

2.4.23 Australia-East Asia Iron Ore Green Corridor

The Australia-East Asia iron ore green shipping corridor represents a collaborative effort between prominent stakeholders, as shown in Table (1) (BHP, 2022; Oldendorff, 2023). This collaborative study has revealed promising prospects for ships powered by clean ammonia to be deployed on the iron ore trade routes between West Australia and East Asia as early as 2028, with an estimated 5% adoption rate by 2030.

As per the scenario analysed, the successful realisation of the corridor could witness the operation of over 20 vessels utilising clean ammonia by 2030 and substantially scaling up to approximately 360 vessels by the year 2050 (GMF, 2023b). The iron ore trade via this corridor encompasses seaborne transactions between Western Australia and East Asian countries, including Japan, Taiwan, China, and South Korea (Boyland et al., 2023).

2.4.24 QUAD Shipping Taskforce

The US, Japan, Australia, and India have launched a new alliance to enhance collaboration and cooperation among major maritime shipping hubs with some of

the world's largest ports called The QUAD Climate Change Adaptation and Mitigation Package (Q-CHAMP). The QUAD countries will continue to convene to facilitate the exchange of knowledge and best practices among their respective governments, ports, and stakeholders. A primary focus of this alliance is to develop a shared framework that will enable the establishment of green corridors within the targeted timeframe of 2025-2030 (MOFA, 2022).

To ensure effective implementation, the QUAD partners will launch a QUAD Shipping Taskforce, inviting leading ports, such as POLA, Mumbai Port, Sydney, and Yokohama, to participate in forming a dedicated network dedicated to advancing the greening and decarbonisation of the shipping value chain (Prime Minister, 2022; The White House, 2021).

Furthermore, the QUAD countries will actively promote efforts to establish clean hydrogen and clean ammonia supply chains as part of an expanded 'Clean Hydrogen and Ammonia Partnership (MOFA, 2022).

2.4.25 US- Fiji- Panama Green Corridor

The US and Panama have announced the establishment of a green shipping corridor. This initiative involves a feasibility study with various stakeholders, including the scientific community, maritime industry, environmental organisations, and coastal communities. It marks the region's first Green Shipping Corridor Initiation Project (DNV, 2023a; US Mission Panama, 2023).

Fiji and the Pacific Blue Shipping Partnership also intend to participate in this corridor. They plan to engage in technical cooperation to support the corridor's establishment. Fiji is also joining the Green Shipping Challenge, an initiative promoting actions to transition toward a 1.5-aligned shipping sector (DNV, 2023a; US Embassy SUVA, 2023).

2.4.26 South Africa- Europe Iron Ore Corridor

A consortium involving Anglo American, Tata Steel, CMB, VUKA Marine, Freeport Saldanha, ENGIE, and the GMF is embarking on a pioneering effort to examine the establishment of a green shipping corridor for zero-emission iron ore transport between South Africa and Europe.

This initiative marks a significant milestone as the first originating from Africa and underscores the region's commitment to decarbonising the shipping industry. The consortium aims to evaluate how zero-emission shipping along this corridor can open up new prospects for South Africa's long-term growth and contribute to a just transition to a zero-emission maritime ecosystem (GMF, 2023a).

2.4.27 Oslofjord- Rotterdam

A green shipping corridor is being established between the Port of Rotterdam and the Port of Oslofjord, with support from Norway through a funding grant. The initiative, spearheaded by Dutch firm Samskip and marine robotics company Ocean Infinity, aims to develop hydrogen-powered, remotely controlled, and autonomous-ready container ships. The project is on track for a potential launch by 2025 and could pave the way for one of Europe's inaugural green corridors (DNV, 2023a; Samskip, 2022).

2.4.28 Rotterdam- Algeciras Green Corridor

Cepsa and the Port of Rotterdam have signed a MoU to create the inaugural green shipping corridor between southern and northern Europe. This corridor will ensure a sustainable hydrogen supply chain connecting two major European ports, Rotterdam and Algeciras. The green hydrogen will be produced at Cepsa's San Roque Energy Park and then transported to Rotterdam, with ammonia and methanol being considered as potential carriers. The partnership anticipates that the corridor will become operational by 2027 (Atchison, 2022; CEPSA, 2022).

Table 1 Green Shipping Corridors MoUs and Projects

No.	Corridor Name	Ports	Type	Ship Type	Fuel Type	Year of declaration	Year of Operation	Parties
2.4.1	Singapore Rotterdam	Singapore Port To Rotterdam Port	Point To Point	Container Ship	Biofuels Methane Hydrogen Ammonia Methanol	2022	2027	Port of Rotterdam, MPA Singapore, Mærsk Mc-Kinney Møller Center for Zero-Carbon, bp, CMA CGM, Digital Container Shipping Association, Maersk, MSC, Ocean Network Express, PSA International, and Shell
2.4.2	Singapore Los Angeles Long Beach	Singapore Port To POLA &POLB	Point To Point	**Not Defined**	**Not Defined**	2022	**Not Defined**	MPA Singapore, Port of Los Angeles, Port of Long Beach, C40
2.4.3	Singapore Australia	Singapore Port To Australia	Point To Point	**Not Defined**	**Not Defined**	2022	2025	Australia's Department of Infrastructure, Transport, Regional Development, Communications, and the Arts (DITRDCA), MPA Singapore, a Statutory Board under Singapore's Ministry of Transport (MOT)
2.4.4	The Silk Alliance	Singapore Asia East Africa Middle East Australia Pacific Islands	Network	Container Ship	**Not Defined**	2022	**Not Defined**	MPA Singapore, PSA, MSC, Pacific International Lines (Pte) Ltd, Wan Hai Lines, X-Press Feeders, Yang Ming Marine Transport Corp., Seatrium, Singfar International, Wärtsilä, Wilhelmsen Ship Management, Asian Development Bank, and ING
2.4.5	Rotterdam Gothenburg	Rotterdam Port To Port of Gothenburg	Point To Point	**Not Defined**	Methanol	2022	**Not Defined**	Rotterdam Port and Port of Gothenburg
2.4.6	Gothenburg North Sea Port	Rotterdam Port To North Sea Port	Point To Point	Car Carrier & RoRo	Biofuels Ammonia Methanol Electric	2022	2027	Rotterdam Port, North Sea Port and DFDS
2.4.7	European Green Corridors Network	Port of Hamburg Port of Gdynia Port of Roenne Port of Rotterdam Port of Tallinn	Network	**ALL**	Biofuels Methanol	2022	**Not Defined**	Mærsk Mc-Kinney Møller Center for Zero-Carbon, Port of Hamburg, Port of Gdynia ,Port of Roenne. Port of Rotterdam, Port of Tallinn
2.4.8	Clean Tyne Corridor	Port of Tyne To European Green Corridors Network	Network	**Not Defined**	**Not Defined**	2023	**Not Defined**	Arup, Connected Places Catapult, EDF Energy R&D UK, Lloyd's Register, Newcastle University, and the Northeast LEP
2.4.9	Nordic Green Corridors	Ports of Nordic Counties	Network	**Not Defined**	**Not Defined**	2022	**Not Defined**	Nordic Cooperation
2.4.10	The Decatrip	Stockholm Port To Turku Port	Point To Point	Ferry Ship	**Not Defined**	2022	2027	Rauma Marine Constructions (RMC), Viking Line, Åbo Akademi University, Kempower, and PBI Research Institute
2.4.11	United Kingdom – France	Ports of Calais Port of Dunkirk Port of Dover	Point To Point	Ferry Ship	**Not Defined**	2023	**Not Defined**	University of Kent, Warwick Manufacturing Group, P&O Ferries, Schneider Electric DFDS, Irish Ferries, Ikigai Capital, JG Maritime Solutions, SSE, and ABB
2.4.12	United Kingdom	Port Aberdeen Orkney Shetland Islands	Point To Point	Autonomous ships	Hydrogen	2023	**Not Defined**	United Kingdom Gov., ACUA Ocean and Unitrove,
2.4.13	Spain Green Corridors	UK Italy United States Turkey Morocco China	Network	**Not Defined**	**Not Defined**	2022	**Not Defined**	Global Maritime Forum and the Energy Transitions Commission in collaboration and British Embassy in Madrid **(Preliminary Assessment)**

2.4.14	Antwerp – Montreal	Port of Antwerp To Port of Montreal	Point To Point	**Not Defined**	**Not Defined**	2022	**Not Defined**	Port of Antwerp and Port of Montreal
2.4.15	Halifax - Hamburg	Port of Halifax To Port of Hamburg	Point To Point	**Not Defined**	Hydrogen Ammonia Methanol	2022	**Not Defined**	Port of Halifax and Port of Hamburg
2.4.16	Great Lakes - St. Lawrence Seaway System	Great Lakes St. Lawrence	Point To Point	**Not Defined**	Biofuels Ammonia Methanol Hydrogen Electric	2022	**Not Defined**	U.S. Department of Transportation, the U.S. Department of State, and Transport Canada
2.4.17	Alaska - British Columbia – Washington	British Columbia Juneau Vancouver Seattle	Network	Passenger & Cruise	**Not Defined**	2022	**Not Defined**	Port of Seattle, Port of Vancouver, City of Juneau, Carnival, Norwegian Cruise Line, Royal Caribbean, CLIA, GMF, Blue Sky Maritime, Washington Maritime Blue, Greater Victoria Harbour Authority, Haines Borough, Haines Borough, City and Borough of Sitka and Municipality of Skagway.
2.4.18	Gulf of Mexico	New Orleans To Houston	Point To Point	**Not Defined**	**Not Defined**	2022	**Not Defined**	Blue Sky Maritime, ABS, Port of New Orleans, Centre for Houston's future and Greater New Orleans Inc
2.4.19	Los Anglos – Shanghai	POLA POLB Port of Shanghai	Point To Point	Container Ship	**Not Defined**	2022	**Not Defined**	C40, Aspen coZEV, Port of Los Angeles, Port of Long Beach, Port of Shanghai, Maersk, CMA, COSCO, ONE
2.4.20	US Japan Green Corridor	POLA Port of Tokyo Port of Yokohama	Point To Point	**Not Defined**	**Not Defined**	2023	**Not Defined**	Port of Los Anglos, Port of Tokyo and Port of Yokohama
2.4.21	ROK-USA Green Corridor	Busan Port Seattle/ Tacoma port	Point To Point	**Not Defined**	**Not Defined**	2022	**Not Defined**	US Government and Korean Government
2.4.22	Chilean Green Corridor Network	Chilean Port Peru Asia Europe	Network	**Not Defined**	Ammonia Methanol Hydrogen	2022	**Not Defined**	Ministries of Energy, Transport and Telecommunications, and Foreign Affairs and Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping
2.4.23	Australia - East Asia Iron Ore	Australia Japan China Taiwan South Korea	Network	Bulk Carriers	Hydrogen	2022	2028	Global Maritime Forum, BHP, Rio Tinto, Oldendorff Carriers, and Star Bulk Carriers
2.4.24	QUAD Shipping Taskforce	POLA Mumbai Port Sydney Yokohama Port	Network	**Not Defined**	Hydrogen Ammonia	2021	2025-2030	US Gov., Japan Gov., Australia Gov. and India Gov.
2.4.25	US – Fiji-Panama	US – Fiji-Panama	Network	**Not Defined**	**Not Defined**	2023	**Not Defined**	US, Panama, Fiji, and the Pacific Blue Shipping
2.4.26	South Africa-Europe Iron ore	**Not Defined**	Network	**Not Defined**	**Not Defined**	2023	**Not Defined**	Anglo American, Tata Steel, CMB, VUKA Marine, Freeport Saldanha, and ENGIE, GMF,
2.4.27	Oslo Fjord-Rotterdam	Oslo Fjord Port Rotterdam Port	Point To Point	Container ship	Hydrogen	2022	2025	The Samskip-Ocean, ENOVA, Norway's Ministry of Climate and Environment
2.4.28	Rotterdam - Algeciras	Rotterdam Port Algeciras Port	Point To Point	**Not Defined**	Ammonia Methanol	2022	2027	YCA, Cepsa, Yara Clean Ammonia, Rotterdam Port

2.5 Green Corridor Implementation

As mentioned earlier, the concept of Green Shipping Corridors has seen considerable progress, with approximately 28 corridors being proposed or planned. While some are still in the study phase, others are scheduled for implementation in the near future. The Singapore-Australia and Oslo fjord- Rotterdam green corridors are expected to be among the first to begin operation in 2025.

It is observed that the majority of these corridors are designed to cater to container vessels and ferries, as shown in Table (1), with only two being tailored explicitly for Bulk carriers. Notably, the Chilean Green Corridor and Rotterdam-Algeciras Green Corridor aim to support tankers, particularly Ammonia carriers, indicating the diversity in the types of vessels targeted for emission reduction.

The Nordic countries demonstrate a solid commitment to implementing green corridors and fostering connectivity among themselves. Similarly, the North Sea and most European countries have well-established connections with Asia, the US, and Canada through these green corridors. As a central maritime hub, Singapore has developed extensive green corridors to facilitate connectivity with the rest of the world.

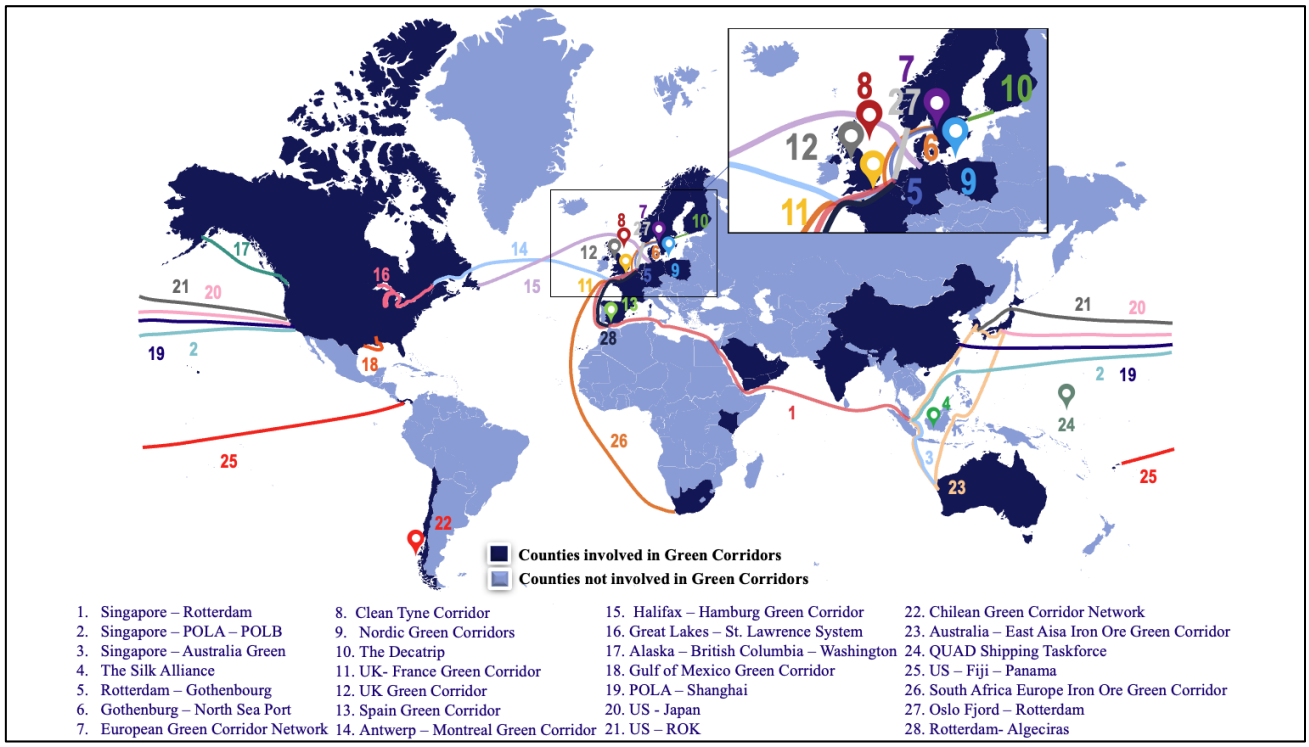

Figure 5 Green Shipping Corridors Map of MoUs and Projects

However, it is evident that green corridors are predominantly concentrated among developed countries, as shown in Table (2) and Figure (5), leaving a recognised absence of such initiatives in developing countries. This disparity highlights a significant gap in equitable access to sustainable shipping solutions, as developing countries still need to be adequately represented in the green corridor network.

Addressing this imbalance is crucial for achieving a more inclusive and comprehensive transition towards greener maritime transportation. It calls for greater attention and support from international organisations and developed countries to collaborate with and assist developing nations in implementing green shipping corridors. By fostering knowledge transfer, technology sharing, and financial support, it is possible to extend the benefits of sustainable shipping practices to a more diverse range of countries and regions. This approach will be essential in realising a more sustainable and environmentally responsible global maritime industry.

Table 2 Interconnected between Countries within Green Shipping Corridors

	Australia	Belgium	Canada	Chile	China	Estonia	France	Germany	India	Japan	Netherlands	Nordic Countries	Poland	Singapore	South Korea	Taiwan	United Kingdom	United States	East Africa	Pacific Island	Middle East	Panama	Spain
Australia					√				√	√				√	√	√		√		√	√		
Belgium			√									√											
Canada		√						√										√					
Chile				√																			
China	√									√					√	√		√					
Estonia								√			√	√	√				√						
France																	√						
Germany			√			√					√	√	√				√						
India	√									√								√					
Japan	√				√				√						√	√		√					
Netherlands						√		√				√	√	√			√						√
Nordic Counties		√				√		√			√	√					√						
Poland						√		√			√						√						
Singapore	√										√							√	√	√	√		
South Korea	√				√					√						√		√					
Taiwan	√				√					√					√								
United Kingdom						√	√	√			√	√	√				√						
United States	√		√		√				√	√				√	√			√				√	
East Africa														√						√	√		
Pacific Island	√														√			√	√		√	√	
Middle East	√													√					√	√			
Panama																		√		√			
Spain											√												

2.6 Alternative fuel

Indeed, alternative fuels play a pivotal role in successfully implementing green shipping corridors. As evident from the existing and planned corridors, adopting alternative fuels is a common denominator in reducing GHG emissions and promoting sustainability in the maritime sector.

The choice of alternative fuel may vary depending on factors such as the corridor's specific route, the type and tonnage of the ship (Law et al., 2022), the fuel's availability in the respective countries, and the support from ports to facilitate the supply of these fuels to ships. The existing infrastructure, technological readiness, and regional energy resources influence the selection of alternative fuels. Some prominent alternative fuels identified for green shipping corridors include Ammonia, Methanol, Hydrogen, Battery Electric Propulsion, and Biofuels, as shown in Table (1).

2.6.1 Ammonia

Ammonia (NH3), a carbon-free chemical compound, has emerged as a compelling alternative fuel for marine applications, garnering significant attention in the shipping industry. One of the key advantages of using ammonia as a marine fuel is its ease of storage and transportation (Moshiul et al., 2023). In Addition, the present output of ammonia fuel is around 180 million tonnes, which is sufficient to fulfil the maritime sector's needs (Y. Wang et al., 2022).

However, it is essential to acknowledge the challenges of using ammonia as a marine fuel. The primary concern lies in its toxicity and hazardous nature. Exposure to high ammonia concentrations in the air can lead to severe health issues (Zhang et al., 2018).

2.6.2 Methanol

Methanol has recently garnered significant attention as a prospective marine fuel, primarily due to its clean combustion characteristics and abundant supply from diverse sources. One of its key advantages in terms of environmental performance is its lower

potential for forming NOx due to its low-in-cylinder combustion temperature (Y. Wang et al., 2021). Another vital advantage of methanol is its liquid state at standard temperature and pressure, making it significantly easier to handle than gaseous fuels (Ampah et al., 2021). This liquid form facilitates storage, transportation, and onboard usage, enhancing operational convenience for ships.

However, it is essential to consider methanol's volumetric energy density, which stands at 15.8 MJ/l, approximately half of the energy density of diesel fuel, which ranges between 36 to 39 MJ/l. This disparity in energy density necessitates a larger volume of methanol fuel storage to achieve comparable vessel endurance as conventional diesel-powered ships (Liu et al., 2019). To fulfil the fuel needs of ships using methanol, ports would have to invest in more extensive storage facilities.

2.6.3 Hydrogen

Hydrogen is recognised as a promising fuel due to its significant environmental benefits. When hydrogen burns, it generates zero carbon emissions, making it a clean energy source. Additionally, the Co2 released during hydrogen production can be minimised depending on the production method employed, enhancing its environmental credentials (Atilhan et al., 2021).

Currently, global hydrogen fuel production stands at approximately 5000 tons per year. One of the advantages of hydrogen is its potential to be derived directly from water through electrolysis, contributing to its widespread availability. However, the high cost of producing hydrogen remains a limiting factor for its large-scale application as a fuel (Y. Wang et al., 2022). Additionally, establishing universally accepted standards and regulations for liquefied hydrogen is a critical challenge in advancing its global adoption (Atilhan et al., 2021).

2.6.4 Biofuels

Biofuels have emerged as a promising solution in the maritime sector's quest for carbon neutrality, offering renewable alternatives for marine propulsion and potentially providing synergistic benefits when blended with traditional fuels (Tan et al., 2022). Among these biofuels, biodiesel stands out due to its compatibility with existing diesel engines, making it a feasible option for blending with conventional diesel (Bengtsson et al., 2012).

Nevertheless, the successful integration of marine biofuels relies on addressing two critical factors: long-term price stability and availability. These aspects are essential in determining biofuels' feasibility and widespread adoption for vessel operations (Tan et al., 2022). Additionally, the availability of marine biofuels hinges on several complex considerations, including agricultural production and land conversion. This entails evaluating the environmental and social implications of producing biofuels from crops and assessing their impact on land use, biodiversity, and food security (Leslie et al., 2007).

2.6.5 Battery Electric Propulsion

The shift towards battery systems as a viable alternative to diesel engines is gaining traction as a practical means to achieve the global 2050 decarbonisation objectives in the maritime industry. Battery-powered ships offer several compelling advantages, including simplified operation and lower maintenance costs compared to conventional diesel systems (Jeong et al., 2022).

The widespread use of large-scale electric energy storage in high-power marine vessels encounters considerable challenges. One central limitation is the batteries' limited energy density and high cost, which restricts the range of purely battery-powered operations. Consequently, vessels relying only on battery-based propulsion systems are presently constrained to coastal and short-distance voyages (DNV, 2018; Karimi et al., 2020).

2.7 Port Vital Role

Ports play a crucial and central role in developing green corridors, but they also encounter various challenges in supporting such initiatives (ABS, 2022). A primary challenge involves establishing and maintaining a strong communication channel between vessel operators and ports throughout the green corridor's development.

During the planning phase, continuous dialogue is necessary to address compatibility and safety requirements for implementing potential solutions. These may include devising unique bunkering arrangements for alternative fuels, incorporating cold-ironing arrangements while vessels are at berth, or integrating emission capture mechanisms during berthing operations (Alamoush et al., 2020; 2022a).

To successfully develop green corridors, ports must ensure access to a reliable supply of alternative fuels. They must have well-organized logistics in place to procure and store these fuels and the necessary infrastructure to ensure safe bunkering procedures (MMMC, 2022a).

Ports that embrace a proactive approach and become early adopters of green corridor initiatives can leverage the framework to enhance their infrastructure capabilities. By doing so, these ports can elevate their status from regional hubs to internationally recognised ones, thereby attracting increased shipping activity and bolstering their significance globally.

2.7.1 Port Barriers

Establishing green shipping corridors navigates a complex landscape involving multiple stakeholders from different sectors, which presents numerous challenges. Building trust and setting common objectives among diverse stakeholders becomes intricate due to their varied backgrounds and geographical locations (GMF, 2022).

This study will concentrate on the challenges ports face in becoming part of the green shipping corridor.

Identifying the main stakeholders involved in the corridor ecosystem across the value chain is essential. Additionally, it is crucial to explore potential alternative fuels, their sources, and types and assess the port and bunkering infrastructure (MMMC, 2022a). Ensuring compliance with regional, national, and international health, safety, and environmental policies is also paramount for ports.

Furthermore, ports face a significant challenge in calculating and understanding the necessary capacity for storage and bunkering within the corridor. Determining how much of the required capacity can be met through retrofitting existing infrastructure and how much additional infrastructure is needed poses further complexities. Evaluating the regulatory feasibility of developing storage and bunkering infrastructure and understanding the required investments and potential financing options is crucial (MMMC, 2022a). Additionally, analysing the government's role and regulatory support in advancing the green corridor is paramount (Arup, 2023). Addressing these challenges will be essential in successfully integrating ports into the green corridor and promoting sustainable maritime practices.

3. Chapter 3: Methodology

3.1 Introduction

This chapter outlines the method and approach employed to address the challenges associated with participating in and implementing a Green Shipping Corridor, focusing specifically on the ports' perspective. It will detail the steps and rationale behind the chosen method, highlighting why it is considered the most effective means to identify the challenges that ports encounter in becoming a part of a green shipping corridor.

3.2 Research Design

The selected research methods are instrumental in shaping the overall outcome of the study, ensuring its accuracy, and establishing its reliability (Alshenqeeti, 2014). The first step of the methodology will be to conduct a literature review, gathering all available reports and scientific papers related to green shipping corridors from various sources. However, due to the limited data availability, the emphasis will be on gathering qualitative information from these sources, including port websites, governmental websites, classification societies, and organisations involved in green shipping corridor initiatives.

Based on the literature review findings, Semi-structured interviews with key stakeholders will be the method to gain comprehensive insights into the implementation challenges from the port's perspective and the impact of green shipping corridors. The interviews were conducted with representatives from ports, classification societies, shipping companies, governmental bodies, and environmental organisations. These interviews will provide first-hand perspectives and experiences

(Jamshed, 2014), enabling a deeper understanding of ports' challenges in integrating green shipping corridors.

The research aims to thoroughly explore the complexities surrounding green shipping corridors despite the limited secondary data availability by employing a qualitative approach and focusing on interviews with key stakeholders.

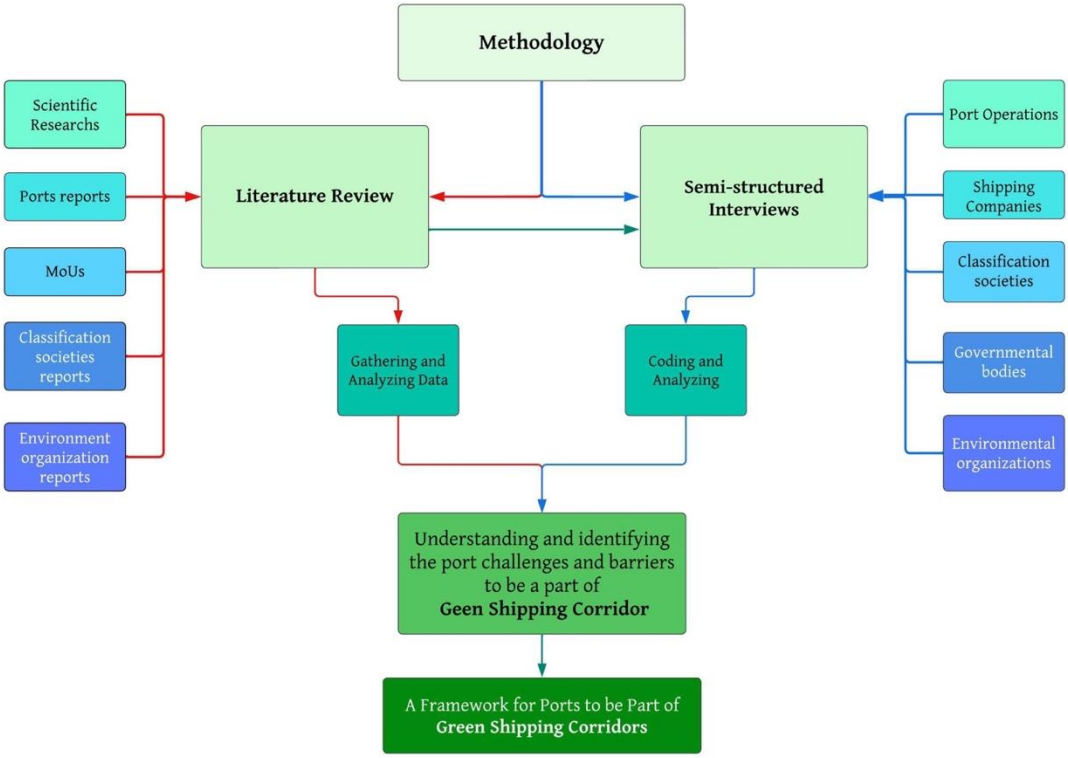

Figure 6 Schematic Representation of Methodology Flow

3.3 Literature Review

Literature reviews have made significant contributions by identifying research gaps in existing literature and presenting research agendas for further exploration (Fragapane et al., 2021). Moreover, they serve as repositories of knowledge acquired by other researchers, playing a crucial role in advancing and enriching the collective understanding of a particular field of study (Schryen & Sperling, 2023).

The secondary data sources for this study encompass various reports from classification societies, including DNV, ABS, and LR, which are actively engaged in green shipping corridor initiatives and cover all related aspects. Additionally, the study will analyse MoUs between countries and ports, investigating the roles of each party involved in these agreements. Government reports outlining their plans for implementing green shipping corridors will also be examined, along with port reviews and reports.

The contributions of environmental organisations are of particular importance which play a central role in the implementation of green shipping corridors worldwide. Notable organisations such as the MMMC have been influential in green corridor initiatives, including those in Chile and between Rotterdam and Singapore. C40 Cities is another critical player in green shipping corridors, exemplified by its involvement in projects like the Singapore – POLA Green Corridor.

While scientific research on green shipping corridors is currently limited due to the novelty of the concept, the study will seek out any available research to complement the data from other sources.

3.4 Interviews

Given the shortage of scientific research and the relatively new nature of the topic, a semi-structured interview approach will be employed to gain a holistic view of the challenges ports face in the context of green shipping corridors. This method offers several advantages, particularly in facilitating a reciprocal interaction between the interviewer and participants, allowing for the improvisation of follow-up questions based on the participant's responses (Kallio et al., 2016). The formulation of the questions was guided by the literature review findings, encompassing outcomes, challenges, and barriers identified in the existing research.

The semi-structured interviews will encompass important stakeholders of green shipping corridors, with a primary focus on port operators, given their central role in the research. Additionally, As shown in Table (3) below, representatives from Ports, governmental bodies, shipping companies, classification societies and environmental organisations will participate in the interviews.

Table 3 Details of Interviewee Participants

Serial no.	Interviewee code	Duration of Interview	Country	Organization	Functions	Years of Experience
1	P1	20 mins	Developed	Port	Energy Manager	18 years
2	P2	25 mins	Developed	Port	Harbour Master	32 Years
3	P3	20 mins	Developing	Port	Ass. Harbour Master	13 Years
4	P4	30 mins	Developing	Port	Energy Manager	20 Years
5	P5	30 mins	Developing	Port	Energy Manager	18 Years
6	G1	20 mins	Developed	Government	Senior Policy Advisor	12 years
7	G2	30 mins	Developing	Government	Head of Flag State	27 Years
8	G3	20 mins	Small Island Developing States (SIDS)	Government	Senior Transport Planer	12 Years
9	S1	45 mins	Developed	Shipping Company	Marine Superintendent	25 Years
10	S2	25 mins	Developing	Shipping Company	Technical Superintendent	15 Years
11	C1	20 mins	Not Applicable	Classification Society	Senior Researcher	16 years
12	E1	20 mins	Not Applicable	Environmental Organisation	Policy Liaison officer	4 Years
13	E2	30 mins	Not Applicable	Environmental Organisation	Program Manager, Green Shipping and Green Ports	9 Years

The participants will be selected from two distinct groups: one comprising Small Island Developing States (SIDS) and developing countries, and the other comprising developed countries. This intentional selection aims to capture differing perspectives from both types of countries within each group. By including stakeholders from various backgrounds and countries, the study will obtain a more comprehensive understanding of the challenges faced by ports in different regions.

This approach is well-suited for exploring this relatively unexplored topic, as it allows for flexibility and adaptability in response to emerging themes and insights.

Throughout the interview process, a significant revelation occurred. Several participants indicated a need for a deeper understanding of the green shipping corridor concept. Consequently, these individuals were selectively omitted from the participant list. However, it is essential that comprehensive briefings on green shipping corridors were provided to these participants. These educational interventions encompassed both the core principles of the concept and the potential role through which their respective organisations could contribute actively to the realisation of green shipping corridors.

3.5 Interviews Questions

Prior to commencing the interview, a concise overview of the study's rationale and the interview's objectives should be provided. It is equally crucial to convey honest interest and appreciation for the interviewee's voluntary participation, ensuring they feel at ease and prepared to commence (Alsaawi, 2014).

The interview questions are tailored to the interviewee's organisational background. The first set of questions targets individuals affiliated with the port, government, classification societies, and environmental organisations. Meanwhile, the second set is designed for those with a background in shipping companies. Although the questions

are similar, minor adjustments have been made to suit each group's expertise and knowledge.

3.6 Data Analysis

After completing the interview process, the analysis stage becomes a multifaceted and complex process. It initiates the transcription of the verbal data into written form. Transcription is deemed valuable as it preserves the authenticity of the interviewee's words, capturing the nuances and expressions embedded in the spoken responses (Alsaawi, 2014).

In the process of interpreting the interviews, we will extract the most relevant and engaging information, label it accordingly, and subsequently categorise it into specific groups. This initial categorisation will serve as a foundation for further data coding, wherein the information will be organised into different themes. These themes may also be subdivided into sub-themes to capture finer nuances and details within the data.

The entire analysis will be qualitative, aiming to provide a rich and detailed exploration of the challenges ports face in their involvement with green shipping corridors. The qualitative approach allows for a comprehensive understanding of the interview data, delving into the complexities and subtleties of the challenges from the perspectives of the interview participants. While the primary analysis is qualitative, the research may incorporate descriptive analysis approaches to complement the findings. This may involve presenting figures or visual representations illustrating specific aspects or trends emerging from the qualitative data. Following this process will enable the development of a comprehensive framework for ports to overcome identified barriers.

4. Chapter 4: Analysis and Discussion

4.1 Introduction

This chapter comprehensively analyses interviews with stakeholders involved in the green shipping corridor initiative. It aims to clarify the perspectives of each participant, delve into the drivers and barriers associated with green corridors, and explore the challenges that ports encounter when striving to become integral to the green corridor concept. Participants were selected based on various stakeholder viewpoints, as shown in Table (4), regarding implementing green corridors.

Table 4 Categorized Interviewee Groups based on Countries and Background.

Background	**Port** (Group P)	**Shipping Company** (Group S)	**Governmental Bodies** (Group G)	**Environmental Organisations** (Group E)	**Classification Societies** (Group C)
Developed Country (Group 1)	P1, P2,	S1	G1		
Developing Country & SIDS (Group 2)	P3, P4, P5	S2	G2, G3		
Not Applicable (Group 3)				E1, E2	C1

Notably, the participant selection process embraced a holistic approach. It encompassed not only stakeholders from developed countries with established MoUs for green shipping corridors but also included participants from developing nations and SIDS. This inclusivity offers a comprehensive understanding of the challenges faced by different stakeholders, reflecting diverse economic and infrastructural contexts.

Indeed, the interviews with stakeholders can be categorised into two different groups. As shown in Table (4), the first categorisation is based on the stakeholder's professional background, which includes shipping companies (Group S), ports (Group P), environmental organisations (Group E), classification societies (Group C), and governmental bodies (Group G). This grouping allows for a focused analysis of how each specific type of stakeholder perceives and interacts with the concept of green corridors. The second categorisation is based on the economic development status of the countries the stakeholders represent. This classification differentiates between stakeholders from developed countries (Group 1), which typically possess established infrastructure and policies, and those from developing countries and SIDS (Group 2), which often face unique challenges in adopting green corridors.

The analysis can yield main and holistic insights by employing these dual categorisations. It allows for a detailed exploration of how stakeholders with varying roles within the maritime sector view and contribute to green shipping corridors. Simultaneously, the distinction between developed and developing countries offers a slight understanding of how economic contexts influence green corridors' perception, challenges, and potential benefits.

4.2 Understanding Green Shipping Corridor

The culmination of the comprehensive investigation of the green shipping corridor definitions presented in Chapter 2 underscores the pivotal essence of the green shipping corridor concept. These specialised maritime routes linking two or multiple ports are focused on prioritising the adoption of low-carbon or zero-carbon fuels and sustainable technologies. This strategic approach serves to reduce maritime transportation's environmental impact significantly. Importantly, the initiative seeks to rally all stakeholders invested in achieving this goal, encouraging active participation in the green corridor endeavour and fostering collective efforts to overcome associated challenges.

As the interview highlighted, the port is central to this transformative vision and a critical stakeholder within the green shipping corridor scheme. The port's pivotal role is anchored in its multifaceted contributions, ranging from providing essential infrastructure to facilitating the supply of alternative fuels and bunkering services. The port is responsible for ensuring strict adherence to safety protocols pertinent to the alternative fuel landscape. The port's proactive involvement remains instrumental in producing the seamless functioning of green corridors. In addition, E2 emphasises, " The port has ample opportunity that they can be that unifying piece through those partnerships. Ports, particularly Singapore and Rotterdam, are leading in establishing green corridors. They actively involve various stakeholders in this endeavour".

4.3 Driving Force for Green Shipping Corridor

The conducted interviews have illuminated a spectrum of drivers motivating ports to establish green shipping corridors. Primarily, these corridors are harmonious with governmental agendas oriented towards reducing GHG emissions. Those corridors display in alignment with international protocols such as the Paris Agreement. Consequently, ports are inclined to actively participate in the initiative, highlighted by the convergence of interests.

A key informant, as G2, generally said, "Our government's consistent engagement in the deliberations underpinning the Paris Agreement's climate change resolutions reinforces our commitment to transitioning from conventional fossil fuels to cleaner energy alternatives.". S1 expresses, "As a leader company, we believe in being involved in such activities. This means we follow rules that are aimed at enhancing vessel emission profiles. We believe this will soon become a standard requirement for operating all vessels emission-free."

Furthermore, the conception and implementation of these green shipping corridors are balanced to generate a heightened public consciousness concerning climate change and environmental imperatives. The ensuing elevation of public awareness can

exercise pressure upon governmental entities and corporate stakeholders across diverse sectors. A respondent, P3, explained this dynamic: "The escalating public knowledge, attending with promoted environmental concerns and the regulatory momentum steering agreement on emission reduction, consistently force the government to institute strict environmental safeguards."

Moreover, all participants concur that stakeholder collaboration is central to green shipping corridors. This collaboration facilitates sharing sustainability goals, enhancing overall environmental performance within the maritime industry. This collaborative approach is also balanced to drive technological and technical innovations in port and ship design, propulsion systems, and the search for optimal alternative fuels. C1 elaborated, "By focusing on specific energy sources like hydrogen or ammonia within specific green corridors, infrastructure development becomes more feasible. This strategy can also facilitate cargo merge, making economic sense."

This stakeholder engagement can confer a competitive advantage in an extended context. By adopting alternative fuels early on, ports can attract eco-conscious shipping companies and cargo owners. This early adoption of alternative fuel can lead to increased business opportunities and market share. Moreover, this could stimulate global trade and support the port's reputation on an international scale. As discussed from E2,” Green corridors represent a notable business opportunity. They provide a chance to gain a significant competitive edge in the market. Additionally, being proactive in adopting green practices allows entities to stay ahead of forthcoming regulations, avoiding potential penalties by ensuring readiness before their implementation”.

4.4 Barriers and Challenges

Analysis of the green shipping corridor interviews exposes vital barriers and challenges that impede ports' successful implementation of such initiatives. These

impediments are discussed herein based on the priority ratings assigned by participants.

Table 5 Interviewee Ratings of Green Shipping Corridor Implementation Barriers

Country Group	Interviewee Code	Cost	Alternative Fuels	Technology & Infrastructure	Government & Regulations	Stakeholders involvement	Awareness & understanding	Operational Complexity
Group 1	P1	2	4	2	1	4	1	3
Group 1	P2	2	4	2	2	4	1	1
Group 2	P3	4	4	4	4	4	2	1
Group 2	P4	4	4	4	4	4	2	1
Group 2	P5	4	4	4	4	4	2	1
Group 1	G1	2	4	4	1	4	1	1
Group 2	G2	4	4	4	4	4	2	1
Group 2	G3	4	4	4	4	4	2	2
Group 1	S1	4	4	4	2	4	2	4
Group 2	S2	4	4	3	4	4	1	4
Group 3	C1	3	4	2	1	4	1	4
Group 3	E1	3	4	2	2	4	2	1
Group 3	E2	4	4	2	3	4	2	1

Code		Score
Very Hard		4
Hard		3
Medium		2
Low		1

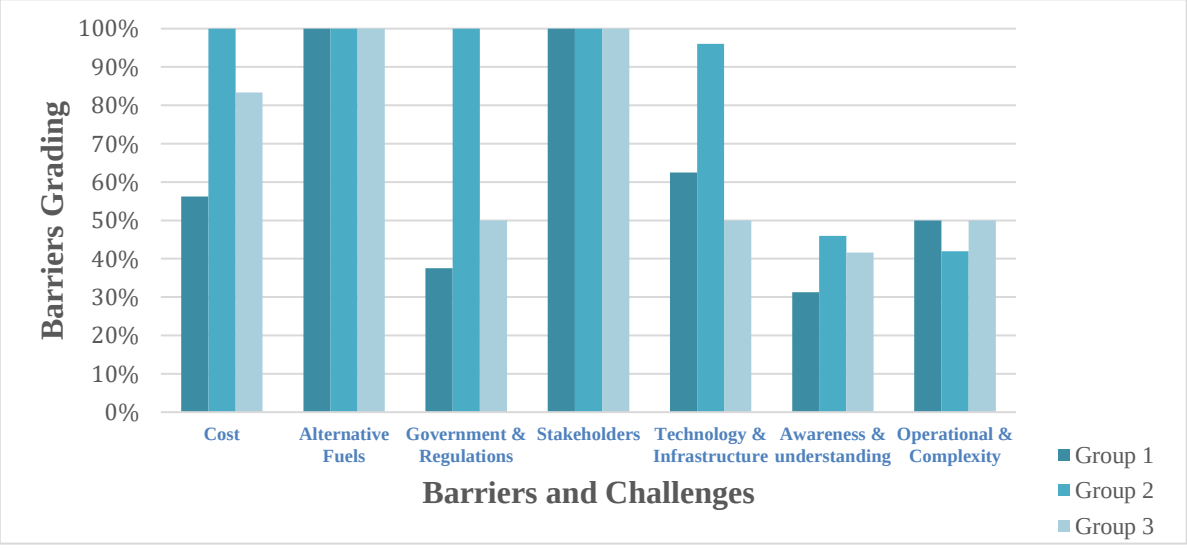

Figure 7 Interviewee Ratings of Green Shipping Corridor Implementation Barriers by Country Groups

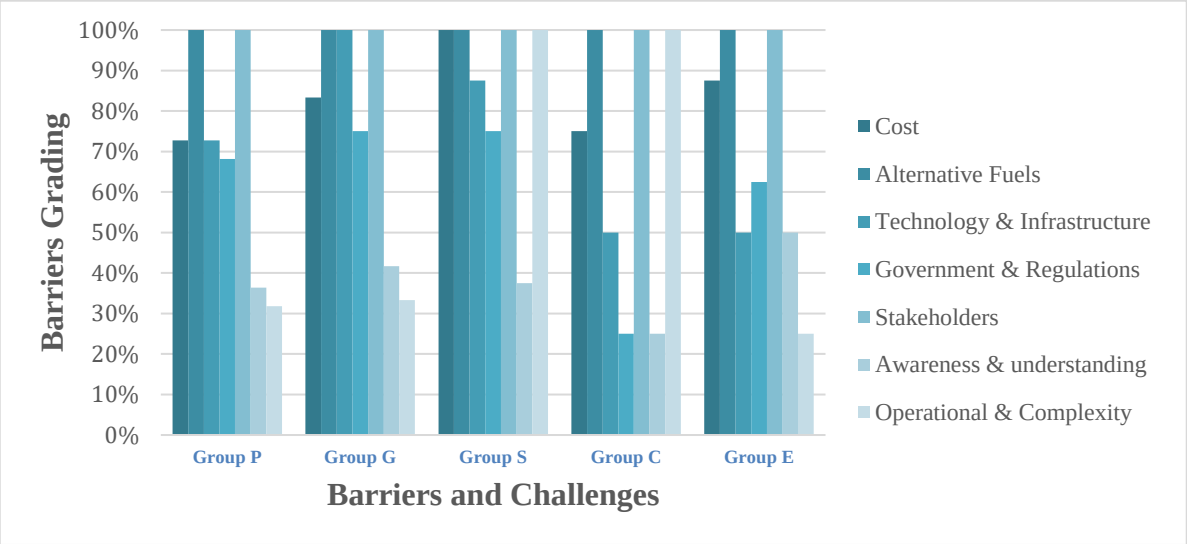

Figure 8 Interviewee Ratings of Green Shipping Corridor Implementation Barriers by Background Groups

4.4.1 Lack of Stakeholders Involvement and Collaboration

Predominantly, stakeholder engagement emerges as the most significant limitation, identified by 100% of respondents. While, as previously discussed, stakeholders play a central role in driving the green shipping corridor concept, this aspect paradoxically presents a significant challenge.

At the interview's outset, the participant emphasised the existence of various stakeholders within green corridors. Among them, a central stakeholder stands out, representing the five vital pillars that form the foundation of these corridors, as shown in Figure (9). These pillars encompass ports, ship owners and operators, energy and marine fuel producers, governments, and cargo owners and charterers.

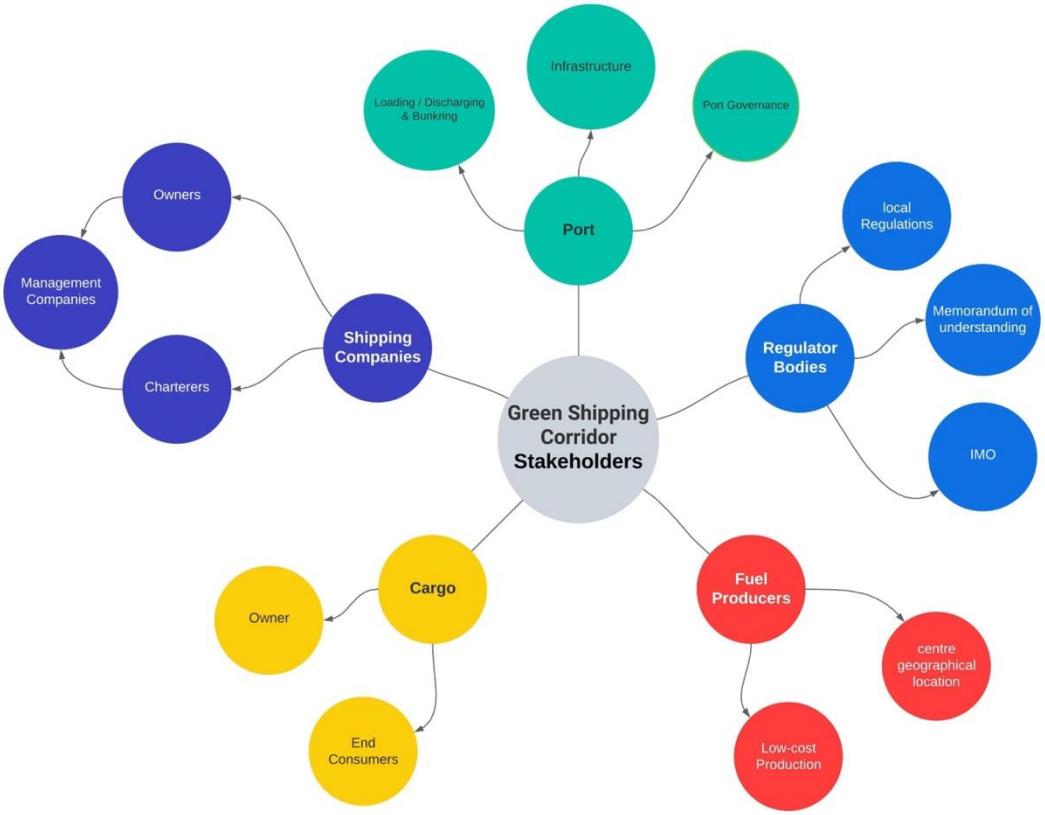

Figure 9 Primer Green Shipping Corridors Stakeholders

Furthermore, the insights shared by interview participants shed light on the distinctive roles each of the five key stakeholders undertakes to ensure the success of green shipping corridors. Ship owners and operators play a pivotal role by procuring new vessels designed to operate on alternative fuels or retrofitting existing ship engines to accommodate such fuels. Energy and marine fuel producers are responsible for developing low or zero-emission alternative fuels. Ports actively reconstruct their infrastructure to facilitate the supply of alternative fuels to ships. Governments drive action by setting emission goals for shipping, providing funding to reduce costs and risks, and supporting the stakeholders to be a part of those corridors. Lastly, cargo owners embrace the role of advocating for emission-free cargo transportation, supporting vessels using alternative fuels, even if it entails additional costs.

Despite the shared willingness to involve all stakeholders, practical implementation faces complexities. At the same time, efforts have been directed towards securing MoUs from various governments and ports. However, the extent of participation from shipping companies remains limited, potentially impeding progress. Notably, the absence of holistic stakeholder engagement poses a challenging obstacle, endangering attaining the green shipping corridor's overarching goals. This underscores the importance of resolving this issue to ensure the corridor's effectiveness and sustainability. G1's observation highlights that "shipping companies are not actively participating in ongoing initiatives. Despite the various announcements and creation of green corridors, most efforts are concentrated among ports. This leaves a significant gap in involving other important stakeholders, particularly shipping companies, in these initiatives".

4.4.2 Limitations in Alternative Fuels

Likewise, the significance of the stakeholder challenge resounds with the limitations posed by the alternative fuel aspect. 100% of the interviewees shed light on various difficulties linked to incorporating alternative fuels. One major limitation is technical, encompassing issues of availability and establishing supply chains for alternative fuels. A significant concern is the limited availability of alternative fuels like hydrogen, ammonia, and methanol (Xing et al., 2021). This absence directly affects the viability of green shipping corridors, potentially creating substantial barriers for ports. Moreover, there are worries among ports regarding the probable unavailability of these fuels after significant investments into building alternative fuel infrastructure for ship bunkering. As mentioned by G2, "The main obstacles mostly rotate around the availability of alternative fuels."

In addition, the second challenge within alternative fuels revolves around safety considerations. Each alternative fuel introduces unique safety challenges in every stage of its transportation, storage, handling, ship bunkering, and operation. An illustrative case is the challenge posed by ammonia's toxicity, presenting a significant obstacle to

the viability of these technologies. The permissible human exposure to ammonia hinges on regulatory frameworks and exposure duration (Valera-Medina et al., 2018). Further, ammonia bears the hazards of being corrosive, flammable, and environmentally undesirable if leaked aboard ships (Kahlouche et al., 2022).

Similarly, methanol poses its safety intricacies, burning with an unseen flame, elevating the safety risk. Additionally, methanol holds toxicity, cautioning against ingestion (Medina et al., 2020). Moreover, worries surrounding the safe handling of these alternative fuels are noticeable. One participant, S1, underscored the safety concerns in managing these fuels and the absence of a comprehensive bunkering manual to guide these processes.

The potential risk shown to port workers and seafarers is a significant concern. P1 underlines this concern “There are substantial health and safety aspects to consider. Overcoming the safety issues of alternative fuels is further complicated because ships often remain operational for 20 to 30 years. Introducing new fuels is not always that easy”. Moreover, P1 reveals, "Following the conversion of our tugboat to hydrogen and ammonia and providing safety training to the crew, many crew members refuse to board due to safety concerns." This poses an additional challenge for the ports.

4.4.3 High Investment Costs

In the context of the interview analyses, a significant obstacle identified is the considerable initial investment cost. The green shipping corridor initiative, grounded in innovative technologies within the shipping sector, necessitates the adoption of environmentally friendly technologies and infrastructure. However, this transition requires a substantial upfront financial commitment, posing a significant challenge for all the stakeholders.

Upon examining the responses from participant Group 1, it becomes evident that the perception of cost as a formidable challenge is not uniformly expressed. Only

Participant S1 acknowledged cost as a major barrier, as shown in Table (5). In contrast, the rest of the participants within Group 1 noted varying degrees of barrier severity, ranging from moderate to high. This disparity implies that developed nations benefit from solid support across stakeholder categories to achieve the ambitious green corridor objective and expedite the completion of zero-emission vessels, as clearly seen in Chapter 2, wherein most green corridors are established in developed countries.

Conversely, it is evident that all participants in Group 2 of the interviews consider the cost a significant limitation in developing a green shipping corridor, as shown in Figure (7). This viewpoint is encapsulated in the statement by Participant S2, who underscores that "The main challenge revolves around the expenses required for retrofitting equipment, addressing bunkering needs, and enhancing the supply chain."

Furthermore, within Group 3, various perspectives on this challenge were noted. However, E2 emphasised a critical point that the substantial infrastructure investment required for green corridors differs significantly from what is typically considered a financially viable project. Therefore, new financing mechanisms must be explored. Traditional banks may hesitate to fund initiatives that do not promise profitability or a clear path to loan repayment. E2 also pointed out that addressing this issue involves navigating complex layers of financial considerations, including insurance, whom to insure for projects with no profit potential and no historical risk data.

4.4.4 Government Involvement and Regulations

According to insights from interview participants, the role of government and regulatory frameworks emerges as a significant obstacle to developing green shipping corridors. The government's influence is pivotal in facilitating the implementation of green corridors. Nevertheless, a closer examination of participant responses shows divergent views between Group 1, Group 2, and Group 3.

In the interview, Group 1 and Group 3 underlined the pivotal role of the government; nonetheless, they stressed the need for enhanced involvement from various stakeholders at this stage. As G1 accentuated, "The necessity for increased engagement from stakeholders other than the government, especially shipping companies."

In contrast, Group 2 clearly emphasises the essential of government involvement and assigns it the highest priority. The absence of governmental support and facilitation could hinder the realisation of green corridors, given that port and shipping companies typically attach to government strategies and regulations. Participant S2 underscores this "At present, the government and flag state show minimum engagement in green corridors, even at a basic level. Also, definitive guidelines outlining the specific requirements for obtaining a green corridor certification and becoming an integral participant are still not provided, creating a lack of clear guidelines."

Moreover, E2 highlights that in some cases, the city owns the port, but the governance structure can be complex, creating uncertainty about roles, decision-making, and where support is most needed. In such situations, involving the city makes sense as it can contribute to permitting and funding efforts.

This variation stresses the noticeable engagement of developed countries' governments in advancing green shipping corridors. However, developing countries show less governmental involvement, a trend particularly evident in port governance structures.

In addition, Factors such as the type of port governance, associated regulations impacting climate action, responsible governing bodies for executing climate mitigation measures, and initiating climate-related actions can differ based on port governance models (Alamoush et al., 2022b; Sugimura, 2023).

Upon analysing Table (1), it becomes evident that a majority of ports participating in green shipping corridors in developed countries are categorised as landlord ports. This difference underscores the regulatory and supportive role played by developed country governments. In contrast, many developing country ports fall under the classification of public service ports. This classification signifies that government involvement extends beyond regulation and support, often encompassing substantial financial investment in corridor development, thereby increasing the challenges faced by governments in these regions.

4.4.5 Technology & Infrastructure

One of the substantial challenges identified through the interviews pertains to technology and infrastructure adjustments. A ratio of 54% of respondents consider this challenge important, standing as a considerable barrier for ports. This challenge is mainly because numerous alternative technologies necessary for establishing green shipping corridors are still in their newborn stages of development. As C1 highlights, "The first barrier is, of course, the corridors' development. That is not easy because many of those technologies are still, to some extent, experimental."

Furthermore, the transition towards eco-friendly technologies indicates the need to overhaul existing port infrastructure, especially concerning bunkering operations. This transition involves retrofitting ports and vessels to accommodate emerging technologies. In addition, a significant constraint emerged regarding limited space within ports for constructing new infrastructure to facilitate the supply of alternative fuels. Moreover, adaptations are necessary for bunkering processes conducted through bunker barges by ship-to-ship (STS) operations, requiring modifications to suit alternative fuels.

Furthermore, the safety considerations of each alternative fuel and the requisite training for both port personnel and seafarers must be considered. Participant P5 underscores this challenge, stating, "I believe that establishing the infrastructure for green corridors is a major obstacle, especially due to the requirement for unexplored

new technologies. This task is particularly challenging in a developing nation like ours, especially given our status as a public service port".

Additionally, Group S supplements this viewpoint by highlighting the need for more expertise and familiarity in handling and resolving issues about standard equipment that is prevalent globally. This challenge extends to sourcing spare parts, prompting extra concerns regarding integrating new technologies. Moreover, recruiting proficient personnel capable of managing and maintaining these systems can be time-consuming and resource intensive. As stated by S2, " The second key challenge lies in expertise. Specifically, the unavailability of manufacturers, experts, and troubleshooting resources poses an actual barrier".

4.4.6 Operational Network Complexity

Moreover, the interviewees underscored the operational complexity in the shipping sector. Group S and Group C emphasise that, Typically, vessels do not sail to simple point-to-point voyages (liner), except for particular cases, for instance, ferries. This operational complexity threatens a vital aspect of the shipping industry's flexibility. This complexity could cause ships to operate between only a few ports, undermining the industry's inherent flexibility. This limitation not only obstructs the commercial viability of shipping operations but also presents significant technical challenges.

Furthermore, the maritime industry encompasses different vessel types and sizes, each with different operational requisites. Bulk carriers, container ships, tankers, and ferries have unique characteristics that influence their ability to integrate new technologies and fuels.

However, from Group S and C's point of view, green shipping corridors could serve as testing grounds or pilot projects for alternative fuel-powered vessels. This approach could help assess their viability within the maritime industry, identify challenges, and make way for problem-solving and advancements in the near future.

4.4.7 Awareness and Understanding

The interviews have underscored the significance of awareness as a primary impediment. Interestingly, while all participants rate it as a moderate or low barrier, the analysis indicates that this does not indicate insignificance but suggests that this obstacle can be overcome efficiently. The absence of awareness and comprehension among stakeholders, including governmental bodies, would restrict progress toward decarbonisation. While overcoming this barrier might not be exceptionally challenging, its absence could obstruct the establishing of green corridors and even broader decarbonisation strategies.

Participant P3 encapsulates all barriers "I believe the high initial investment costs for adopting green technologies and infrastructure and the limited availability of the high costs for sustainable fuels, energy sources, technology challenges such as developing countries and the change of existing infrastructure to meet the green standers. Also, there is a lack of awareness and understanding of the benefits of green corridors among stakeholders".

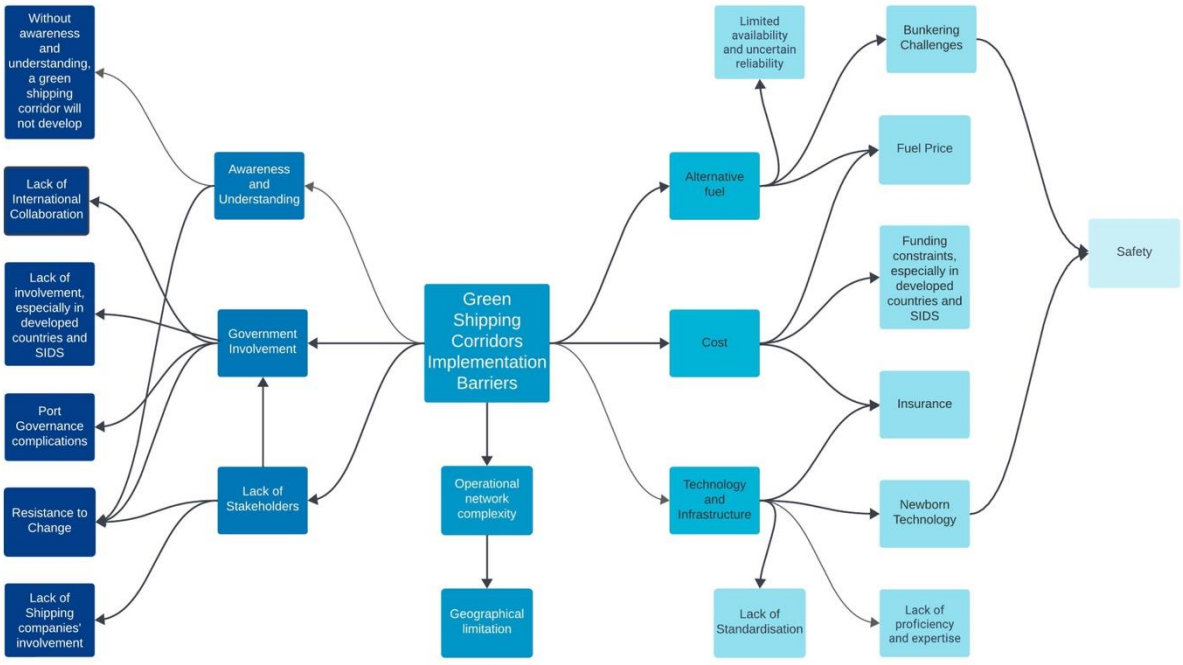

Figure 10 The interviewees' opinions regarding the barriers faced by ports when participating in green corridors.

4.5 Effectiveness and Opinions

The analysis of the interviews underscores the participants' optimistic perspective on the efficacy of green shipping corridors. These corridors possess the potential to revolutionise the shipping industry, steering it towards a more environmentally conscious revolution. As declared by G1," the green corridors stand as rich conceptual frameworks."

Moreover, the impact of green corridors will be substantial, acting as real-world laboratories to trial unknown technologies. This experimental space empowers shipping entities to explore new fuels and engine models, a transformation attainable only through the collaborative engagement of industry stakeholders, as emphasised by P5.

The ripple effects of this initiative encompass market transformation and push demand for sustainable alternative fuel. This shift will promote the importance of climate-conscious initiatives, ultimately charting a course for decarbonising the shipping sector. P1 further declares that "green corridors could fundamentally reshape perceptions of the sector, paving the way for a more universally embraced and eco-friendly mode of transportation."

Table 6 Interviewee's Perspectives on Green Shipping Corridor Support and Concerns

	P1	P2	P3	P4	P5	G1	G2	G3	S1	S2	C1	E1	E2
Support	√	√	√	√	√	√		√				√	√
Have Concerns							√		√	√	√		

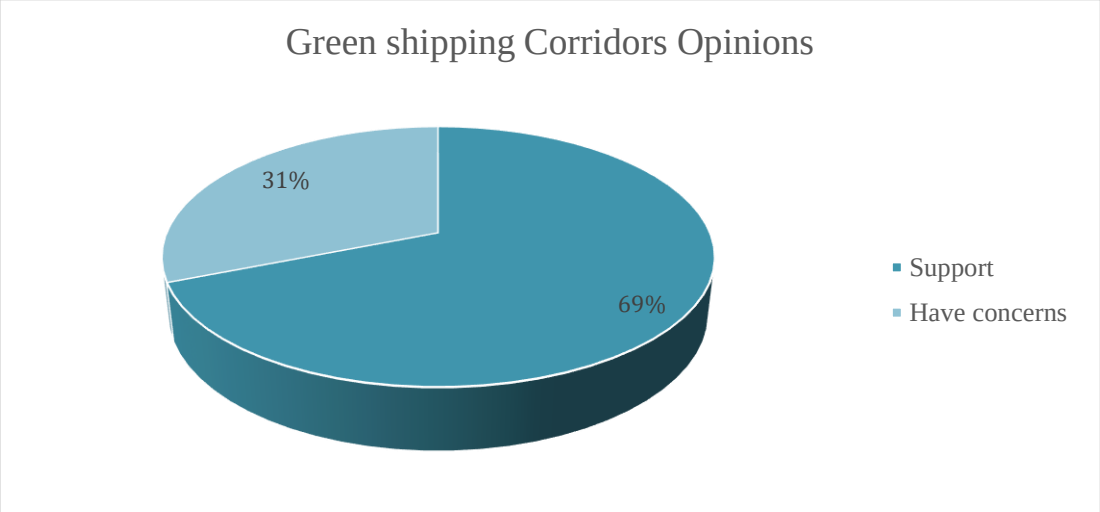

Figure 11 Percentage of Interviewee Support and Concerns for Green Shipping Corridors

Participants unanimously perceive green shipping corridors as a pivotal step towards a sustainable maritime sector. They view these corridors as transformative instruments, unifying diverse industries under one umbrella project that international organisations and governments maintain. The collective effort addresses challenges systematically.

However, 31% of participants, as shown in Figure (11), mainly from Groups S and C, hold reservations and concerns about green corridors. C1, reflecting doubt, proposes that vertical collaborations between suppliers, transport providers, and customers might be more effective in fuel transition than geographically restricted corridors, which can delay the transaction period. G2 expresses concerns about the feasibility of this approach in developing nations, apprehending forced implementation without fair readiness. He fears its repercussions on developing economies and the global trade network and the reaction of these countries, which can affect negatively.

Nevertheless, during the SeaEnergy project seminar held at WMU in October 2023, the Maritime Technology Cooperation Centre (MTCC) Africa representative pointed out that no concrete steps have been taken in collaboration with the SILK Alliance to involve West African ports in the green corridor. This has resulted in a discrepancy

between the information presented in the reports and the actual developments in real life (MTCC Representative, 2023).

S1 asserts that while green corridors offer environmental benefits, the transportation sector might not reap proportional advantages due to added requirements leading to higher costs and potential inflation. S1 added that shipping companies face challenges sticking to the Carbon Intensity Indicator (CII) regulations, particularly concerning long anchorage vessels. This unfeasible calculation approach has led to a loss of trust among ship owners in the effectiveness of decarbonisation regulations, even for newly constructed ships in 2022.

This situation has instilled a sense of worry among shipping companies, discouraging them from investing or participating in initiatives such as green corridors. S2 raises an equity concern, highlighting that small and medium shipping companies might suffer when participation becomes mandatory, as only large companies possess the resources and expertise to comply".

Group S underscores that the current MoUs for green corridors present a complexity. Each port commits to supporting alternative fuel types, posing challenges, particularly for longer routes. For instance, a ship using hydrogen between Rotterdam and Singapore may face uncertainties about refuelling points along the route. Less fuel or miscalculations could lead to unplanned stops. Moreover, vessels might necessitate docking outside the designated green corridors for maintenance.

P4 highlights a crucial issue related to port preparedness. He emphasises that alternative fuels for bunkering should not be restricted to vessels participating in green corridors alone. All vessels requiring bunkering of these fuels should be accommodated. Failing to do so could lead to potential environmental disasters when vessels run out of fuel. Additionally, considering the significant investment made by ports, there is a need for a shorter payback period for sustainability.

P3 raised concerns about their port's global ranking. They are currently from the top-ranking ports, and any changes that could impact their ranking are a source of concern. To maintain their status, they are even willing to consume more fuel by having tugs on standby. This highlights the lengths to which ports may go to preserve their position in the industry. This mindset clearly reflects that, for most stakeholders, continuing with business as usual is a safe and preferred option.

However, Group E stresses the importance of viewing green corridors itself as a practical solution for the decarbonisation of the shipping industry. E1 sees green corridors as a pivotal tool for prompting transition, aligning with socio-technical transition theory. Moreover, E2 cautions explicitly against using green corridors as an umbrella and puts every climate-related problem on it. They argue that green corridors already present significant challenges, and overloading them with climate problems would make the task more difficult.

4.6 Interlinking Green Ports and Green Corridors

Upon reviewing the definitions of green shipping corridors outlined in Chapter 2, there appears to be no direct connection specified between green shipping corridors and green ports, nor any mandate that participating ports must be classified as green ports.

However, when participants were questioned about this connection during the interview, 100% indicated that any port could be part of a green shipping corridor. They emphasised that the green corridor primarily focuses on ships, requiring them to operate with low or zero emissions.

Nonetheless, 92% of participants also believed that only proactive ports committed to becoming greener would actively participate in such a corridor. C1 elaborated on this by stating, "Definitely, you would imagine that the ports on the green corridor would also be proactive in becoming greener, because otherwise, why would they invest in..."

He added, "The corridor is focusing primarily on ships. However, if you are producing green ammonia, you must have developed an infrastructure set that allows you to do that. You need to have renewable energy accessible; you need to have the infrastructure for fuel production. So, you can be bunkering zero-carbon fuels on a green corridor".

In addition, C1 added, "Nevertheless, I think the transition is not only about providing Green Corridor with green or alternative fuels. I think that transition requires a transition in all the processes". E2 also emphasised the inclusion of ports in green initiatives, stating that it makes the most sense. E1 suggested that for a large-scale, end-to-end demonstration of green practices, it is best if all stakeholders, including ports, actively participate in environmentally friendly initiatives. This approach is seen as fair and inclusive for all involved parties.

4.7 Overcoming Barriers

The green shipping corridor project is currently in its planning phase, with implementation scheduled from 2025 to 2030 (Lu et al., 2023). Various challenges and barriers must be addressed accurately to successfully maintain these corridors' operation. Furthermore, additional limitations will likely appear once the green corridors are operational.

Some interviewees offered solutions to address these challenges and barriers. Regarding stakeholder involvement and collaboration, Group S proposed that governments and ports could incentivise ship owners to join the green shipping corridors by reducing taxes for participating vessels, lowering port fees, and offering priority berthing. This approach could motivate ship owners to invest in these corridors.

S1 emphasised that motivations are crucial, suggesting that allowances for environmentally friendly fuel usage could lead to fee reductions and priority berthing.

They cautioned that current practices of imposing fines on non-compliant vessels could discourage participation due to high costs relative to profits. S1 recommended facilitating low-cost services like Shore power with significant capacity to encourage participation. Drawing a parallel with waste disposal services, they highlighted that providing such services at minimal or no cost can incentivise users and result in cleaner practices. These insights underscore the importance of offering feasible and economical solutions to encourage broader engagement in green shipping corridors.

G2 emphasised regarding government involvement that developing countries require international support, particularly from organisations like the World Bank and IMO, to successfully implement such a massive project as the Green Corridor. Given the scale of transformation needed, this collaborative approach is viewed as more sustainable. Additionally, G2 recommended that developed countries include developing nations in their ongoing initiatives, avoiding leaving them behind in the transition and creating a level playing field.

P4 underscored the pivotal role of ports in advocating for favourable regulations and policies at the governmental level. Ports can emphasise the positive impacts of green corridors on the economy, environment, and society. Furthermore, P4 suggested active engagement with government bodies to contribute to creating regulations that promote adopting sustainable practices within the shipping industry.

S1 proposed a phased approach to address the operational complexities by initially treating green corridors as pilot projects. Subsequently, merging or integrating these corridors could enhance the flexibility of ships to access different ports and overcome geographical limitations. S1 also highlighted the importance of data-sharing platforms to enhance communication and coordination among the entities engaged in the corridor.

E2 also stressed the importance of a carbon tax as a fair solution to promote the use of alternative fuels. According to E2, shipping companies should pay the actual fuel cost, considering the environmental harm it causes. They pointed out that the current pricing, especially for OPS, can be unfair. In Europe, many ports have invested significantly in providing OPS, but ships often prefer burning fuel due to lower prices.

However, E2 noted that the carbon tax should not be punishing. It should serve as a strong incentive for choosing greener options rather than punishing those who do not. Hitting the right balance to encourage the adoption of green technologies while not driving business away presents a challenging task for policymakers.

E1 suggests that governments can support green corridor development through various interventions. In the early stages, they can encourage industry consortiums to explore corridors, steering them toward promising routes. Later, the focus should shift to facilitating private-sector investments. Governments can help close the fuel cost gap by supporting fuel certification schemes, expediting permitting and approvals processes, and upskilling seafarers for zero-emission fuels. They can also provide financial support like loan guarantees and capex subsidies and facilitate knowledge exchange among initiatives. Importantly, E1 emphasises that without national and regional government action, it will be unattainable for green corridors to start operating by the mid-2020s, as IMO action does not align with these timelines.

Finally, the interviewees shared the perspective that specific barriers may gradually diminish over time. They anticipated that challenges related to alternative fuel availability and technological barriers would likely subside due to increasing demand and collaborative efforts between ports and technology testing. This anticipates a positive course for the viability and effectiveness of green corridors.

5. Chapter 5: Green Corridor Framework for Ports

Upon completion of data analysis and subsequent discussion in Chapter 4, a comprehensive framework analysis is conducted to identify, describe, and interpret critical patterns within and across cases, illuminating themes pertinent to implementing green shipping corridors by ports (Goldsmith, 2021). The framework adoption was judiciously selected owing to its proven efficiency in studying extensive, intricate qualitative datasets, aligning seamlessly with the researcher's analytical approach (King & Brooks, 2018).

The framework analysis unfolded through a systematic progression encompassing five distinct stages as follows: data familiarisation, identifying a thematic framework, indexing all study data against the framework, charting to summarise the indexed data and mapping and interpreting patterns found within the charts (Goldsmith, 2021).

The framework analysis began by familiarising the researcher with the dataset and gaining an in-depth understanding of its grasp. Subsequently, the researcher constructed a framework to outline essential components and principles for ports' implementation of green shipping corridors.

In the framework identification stage, the researcher focuses on a detailed analysis of themes and codes in the interview and literature data. This process scooped additional appropriate concepts to enrich the framework. Grouping these codes and concepts, the researcher aimed to address the barriers that ports encountered in adopting green corridors and developed strategies to overcome these challenges.

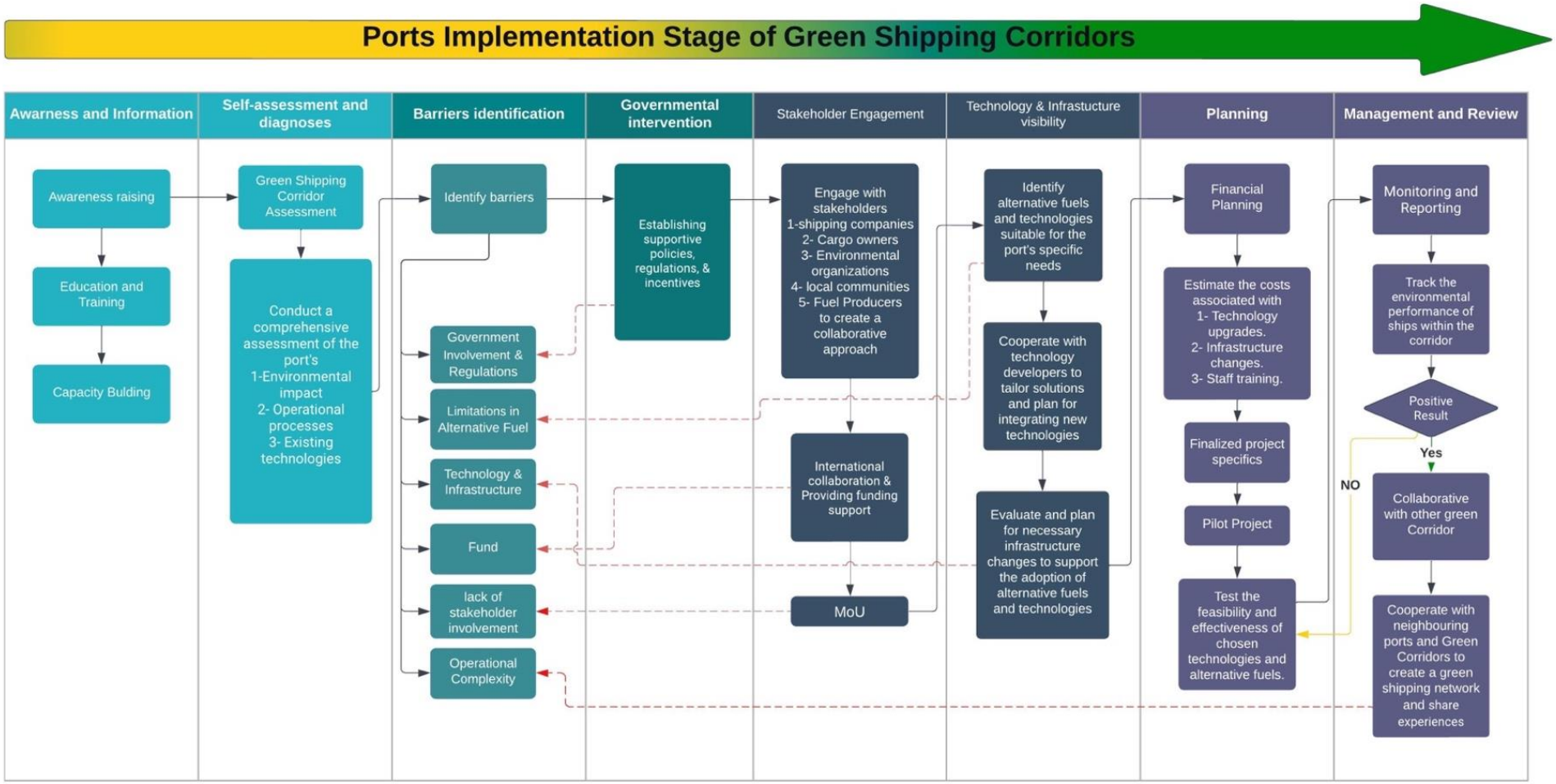

Figure 12 A Framework for Ports in Green Shipping Corridor Implementation and Challenge Overcoming

The indexing phase, the third step, involved aligning the framework elements with relevant study data. The researcher systematically applied the framework to all study data, bringing together data relevant to each barrier. This approach facilitated a comprehensive view of each challenge and enabled the exploration of potential solutions. In the charting phase, the fourth step, the researcher created a structured chart outlining different stages to guide ports through the process of becoming part of green corridors.

Figure (12) demonstrates that the framework consists of eight sequential steps. It begins by fostering awareness within the port authority about green corridors and capacity building, which are foundational to any port transformation.

The second step involves self-assessment, where the port evaluates its environmental impact, operational processes, and existing technology to understand the gap between its current state and the requirements for participating in a green corridor. This leads to the third step, where the port identifies barriers and challenges to its involvement.

From the 4th to the 8th step, each phase is designed to address identified barriers. Step four focuses on government involvement, pivotal for establishing green shipping corridors through policies, regulations, and incentives. The government's early involvement aims to establish a strong foundation for building the corridor and encouraging stakeholders to participate, particularly in SIDS and developing countries, and especially in the context of public service port governance.

This leads to step five, involving stakeholders by evaluating market dynamics and cargo flows to select promising green corridors. The port entices participation via incentives, fostering collaboration and international partnerships supported by global funds and MoUs. Step six emphasises technology and infrastructure. Ports identify

suitable fuels and technologies, collaborating with developers to integrate these into existing infrastructure.

In step seven, the port engages in financial planning, outlining necessary technology upgrades, infrastructure enhancements, and staff training. Subsequently, the project is finalised, and implementation procedures are initiated. Once preparations are complete, a pilot project is launched to assess the effectiveness of the chosen alternative fuel and technology.

In the final step, ongoing monitoring of the environmental performance of the green corridors is essential. Adverse outcomes prompt a revisit to step seven for technology and fuel evaluation. Conversely, positive results lead to collaborating with neighbouring ports' green corridors, expanding the geographical scope, and reducing operational complexities.

6. Chapter 6: Conclusion and Recommendation

6.1 Summary of Work

This research addresses the challenges ports face in their efforts to become part of green shipping corridors. This is achieved through a comprehensive literature review and interviews with stakeholders from diverse backgrounds, including developed and developing countries. It is meaningful that 28 green corridors are currently under development, with the implementation expected between 2025 and 2030. However, it is striking that most of these corridors are located in developed countries. This raises the critical question of why developing countries are not actively participating in such initiatives.

The analysis of interviews conducted reveals that the limitations concerning the availability of alternative fuels and stakeholder engagement are vital barriers identified by all interviewees. Additionally, respondents from developing countries prioritise concerns related to funding, government involvement, and regulatory factors. Furthermore, technology and infrastructure, awareness and understanding, and operational complexity are significant barriers to pursuing green corridors. Among the interviewees, there is a blend of support and concerns regarding green corridors. Notably, shipping companies appear inclined to delay the transition to cleaner energy sources to avoid additional costs.

The research findings have led to the development of a framework that can serve as a valuable resource for ports looking to establish green corridors. This framework offers guidance on navigating and overcoming the challenges associated with corridor implementation.

Despite the many barriers impeding decarbonisation efforts in the maritime industry, the green corridors stand out as a prominent solution. These corridors are distinguished for their capacity to encourage collaboration among all stakeholders. This collaborative approach is seen as instrumental in overcoming the barriers to achieving decarbonisation within the maritime sector and creating future-proof vessels (FPV).

It is important to acknowledge that green shipping corridor projects are relatively new, with only about two years of existence, which is a short timeframe in the shipping industry. Currently, green corridors have yet to commence operations, and various challenges are anticipated to arise once they do. Despite these challenges, maintaining optimism and determination is crucial as we desire a more sustainable future.

6.2 Recommendation

Given the newness of green shipping corridors, it becomes urgent for current stakeholders involved in these initiatives to enable transparency by openly sharing what is succeeding and failing and offering insights on how the broader maritime industry can participate and benefit from these corridors. This collaborative approach can contribute significantly to the development and success of green corridors while encouraging wider industry involvement.

Nevertheless, the perspective of ports needs to develop. Ports should not just seek fuel suppliers; they should become future energy hubs capable of producing green fuel. Initially, this might involve setting up a small production unit sufficient to fuel a single tugboat. Subsequently, it can expand and develop this capability. This transformation would enable ports to take a more proactive role in supplying green fuels to ships and contribute to sustainability efforts.

Indeed, a green shipping corridor must encompass not just the ships but also the ports at both ends of the corridor. Starting from a green port and ending in another green port ensures that the entire journey aligns with the goal of decarbonisation. This

comprehensive approach, involving both the vessels and the port infrastructure, raises the environmental benefits and sustainability of the entire shipping route.

Lastly, involve SIDS and developing countries in the existing MoUs of green shipping corridors, ensuring equal opportunities and a level playing field for all nations.

6.3 Future Research

The research has presented a framework that, when implemented, can help ports overcome the challenges they face when joining green shipping corridors. However, it is essential to note that these corridors involve various stakeholders with unique barriers and considerations. As a result, future research avenues could include:

1. Exploring the specific barriers experienced by different stakeholders within the green shipping corridor as they seek to become part of these sustainability-driven initiatives.
2. Examining the development of sustainable port infrastructure and conducting cost-benefit analyses to assess the economic viability of ports participating in green shipping corridors.
3. Conducting comprehensive environmental impact assessments to evaluate green shipping corridors' overall sustainability and environmental advantages, considering both direct and indirect effects.

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Appendices

Appendix 1

Interview Question No 1

1. What are the barriers and drivers for applying Green Shipping Corridors?
2. What is your opinion on Green Shipping Corridors, and how do you think they can benefit the transportation industry and the environment?
3. How does the port work with other stakeholders, such as government agencies, shipping companies, cargo owners and environmental organisations, to promote Green Shipping Corridors?
4. How do you think Green Shipping Corridors fit into the larger context of sustainability and environmental responsibility in the transportation industry?
5. Are there any specific policies or regulations that could be implemented further to promote the adoption of Green Shipping Corridors in the industry?

Interview Questions No 2

1. How aware is your company of the concept of Green Shipping Corridors, and what efforts have been made so far to integrate sustainable practices into your shipping operations?
2. What are the barriers and drivers for applying Green Shipping Corridors?
3. What is your opinion on Green Shipping Corridors, and how do you think they can benefit the transportation industry and the environment?
4. Are there any specific policies or regulations that could be implemented further to promote the adoption of Green Shipping Corridors in the industry?
5. What kind of collaborations or partnerships has your company engaged with other stakeholders, such as ports or energy providers, to promote sustainability and reduce the environmental impact of shipping?
6. How do you think Green Shipping Corridors fit into the larger context of sustainability and environmental responsibility in the transportation industry?

7. In the Green Shipping Corridors context, what specific facilitation measures or incentives do you believe ports can provide to shipping companies to encourage the transition towards cleaner shipping practices?