



Effect of carbon dioxide reduction measures and advanced shipping solutions
on efficiency and productivity

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Chapter 1: Introduction

Carbon dioxide reduction measures are strategies and actions that aim to reduce the amount of carbon dioxide (CO₂) emissions released into the atmosphere. These measures are critical in mitigating climate change, as carbon dioxide is a significant contributor to the greenhouse effect (Mikhaylov et al., 2020). Enhancing energy efficiency is a means to decrease the emission of carbon dioxide. Reducing the energy required can be achieved by enhancing the energy efficiency of vehicles, appliances, and buildings. Additionally, using renewable energy sources such as solar, wind, and geothermal has the potential to lower the consumption of fossil fuels and minimize the release of carbon dioxide into the atmosphere. An approach to reducing carbon dioxide emissions is to implement carbon capture and storage (CCS) technology (Paltsev et al., 2021). This technique seizes the carbon dioxide discharges from power plants and industrial activities, and deposits it beneath the earth's surface or in other long-term storage solutions. Reducing deforestation is also essential in reducing carbon dioxide emissions. Deforestation contributes to carbon dioxide emissions by reducing the number of trees that can absorb carbon dioxide. Implementing forest conservation programs and reforestation efforts can help reduce emissions. Encouraging sustainable transportation is another way to reduce carbon dioxide emissions. Promoting public transportation, walking, and cycling can reduce the number of vehicles on the road and decrease carbon dioxide emissions from transportation (Wang et al., 2022). Implementing carbon pricing can incentivize businesses to reduce their carbon dioxide emissions by assigning a financial cost to each ton of CO₂ emitted (Villena & Dhanorkar, 2020). A combination of these measures and others has the capability to decrease carbon dioxide emissions and alleviate the consequences of climate change.

Advanced shipping solutions refer to innovative technologies and strategies used in the maritime industry to improve the efficiency, safety, and sustainability of shipping operations. These solutions leverage cutting-edge technologies such as automation, artificial intelligence, and big data analytics to optimize vessel performance, reduce emissions, and enhance the overall shipping experience. One example of an advanced shipping solution is the use of autonomous vessels. Autonomous ships rely on a combination of sensors, cameras, and GPS technology to navigate without a human crew on board (Zhang et al., 2021). This technology can increase safety by reducing the risk of human error and can also improve efficiency by optimizing vessel routes and reducing fuel consumption. Another advanced shipping solution is the use of big data

analytics to optimize vessel performance (Munim et al., 2020). This technology can collect data from multiple sources, such as weather forecasts, sea conditions, and vessel data, and use it to create predictive models that can optimize vessel speed, route, and fuel consumption. This can result in significant fuel savings and reduced emissions. Advanced shipping solutions can also help reduce emissions by using clean energy sources such as liquefied natural gas (LNG), which produces fewer emissions than traditional bunker fuels. Other solutions include the use of scrubbers to remove pollutants from exhaust gases and the installation of energy-efficient equipment such as LED lighting and electric propulsion systems (Munim et al., 2020). In addition to these technological solutions, advanced shipping solutions also include new business models and strategies that can improve the sustainability of shipping operations. For example, the use of slow steaming, where vessels travel at reduced speeds, can reduce fuel consumption and emissions. Collaborative shipping arrangements, such as sharing vessels or cargo, can also reduce emissions and improve efficiency (Munim et al., 2020). Advanced shipping solutions are crucial in improving the sustainability and efficiency of the maritime industry. These solutions leverage innovative technologies and strategies to optimize vessel performance, reduce emissions, and enhance the overall shipping experience. By implementing these solutions, the maritime industry can continue to grow and thrive while reducing its impact on the environment.

The maritime industry has a responsibility to consider carbon dioxide reduction measures and advanced shipping solutions as a priority agenda for several reasons. The industry is a significant contributor to global carbon emissions, accounting for around 2-3% of greenhouse gas emissions (Al-Aboosi et al., 2021). With concerns about climate change and the need to reduce carbon emissions, the industry has a responsibility to address this issue and reduce its environmental impact. Secondly, there is increasing pressure on the industry to reduce its carbon emissions, both from national and international regulatory bodies. The International Maritime Organization (IMO) has set targets for reducing greenhouse gas emissions from shipping, and countries around the world are implementing policies and regulations to encourage the adoption of carbon reduction measures (Serra & Fancello, 2020). Failure to comply with these regulations can result in penalties and fines for shipping companies. Implementing carbon reduction measures and advanced shipping solutions can also provide economic benefits for the industry. For example, more fuel-efficient ships can reduce operating costs and improve profitability. Additionally, companies that demonstrate leadership in sustainability and carbon reduction may

have a competitive advantage in the market, as consumers and stakeholders increasingly prioritize sustainability. Moreover, shipping companies are under increasing pressure to demonstrate their commitment to sustainability and reduce their environmental impact. Failure to do so can result in reputational damage and negative perceptions from stakeholders, such as investors, customers, and employees. By prioritizing carbon dioxide reduction measures and advanced shipping solutions, companies can improve their reputation and meet stakeholder expectations. The maritime industry should prioritize carbon dioxide reduction measures and advanced shipping solutions for environmental, regulatory, economic, and reputational reasons. By embracing sustainable practices and reducing their carbon emissions, shipping companies can adapt to the changing global landscape, remain competitive, and thrive in the future.

The current study is focused on the maritime management and the study analyzes the effect of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity.

The Problem and Challenge

While carbon dioxide reduction measures and advanced shipping solutions have significant benefits in reducing emissions and improving sustainability in the maritime industry, they also present a challenge to efficiency and productivity. One of the main challenges is the high cost of implementing these solutions, which can impact the profitability of shipping operations. For example, the cost of retrofitting existing vessels with new technologies such as scrubbers, LNG engines, or automated systems can be prohibitive for some companies (Balcombe et al., 2019). Additionally, the increased time and resources required to implement these solutions can reduce the efficiency of shipping operations, as vessels may need to be taken out of service for extended periods for retrofitting or testing. The complexity of implementing these solutions can also impact productivity. Many of these solutions require specialized skills and training, and the integration of new systems and technologies may require significant changes to existing business processes and workflows.

Another challenge is the potential for regulatory compliance issues. Many carbon dioxide reduction measures and advanced shipping solutions are subject to regulations and standards, and companies may face penalties or fines if they fail to comply (Benhelal et al., 2021). Ensuring compliance can add an additional layer of complexity and cost to implementing these solutions.

There is a potential risk of technological obsolescence. As new technologies and solutions are developed and implemented, older solutions may become obsolete, and companies may need to continually invest in new solutions to remain competitive. This ongoing investment can impact profitability and productivity in the long term. While carbon dioxide reduction measures and advanced shipping solutions offer significant benefits to the maritime industry, they also present challenges in terms of cost, efficiency, and productivity. Addressing these challenges requires a careful balance of investment, planning, and regulatory compliance to ensure that these solutions are both effective and sustainable in the long term. This study acknowledges this need and presents tangible outcomes of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity.

Impact and Cost of the Problem

The challenges related to the implementation of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry can have significant impacts and costs, both in the short and long term. Some of these impacts and costs may include:

Current Issues of the Maritime Industry

Some of the current issues facing the maritime industry include the need to reduce carbon emissions and improve sustainability, while also maintaining or improving efficiency and productivity. The International Maritime Organization (IMO) has established an objective of diminishing shipping's greenhouse gas discharges by at least 50% by 2050, in comparison to the levels recorded in 2008, which presents a significant challenge for the industry (Serra & Fancello, 2020). Another issue is the increasing complexity of regulations and standards governing shipping operations, which can create compliance challenges and increase costs for shipping companies. There is also a growing demand for transparency and accountability in the industry, with stakeholders increasingly seeking information on the environmental and social impacts of shipping operations. In addition, the industry is facing increasing competition from other modes of transportation, such as air and rail, as well as emerging technologies such as autonomous ships and drones. This competition is driving innovation and change in the industry, but also creating new challenges and uncertainties.

Capital and commercial issues

Implementing advanced shipping solutions and carbon dioxide reduction measures can require significant capital investment, which can impact the profitability of shipping operations. Retrofitting existing vessels with new technologies or purchasing new vessels with advanced features can be expensive, and may require financing or borrowing. Additionally, the increased time and resources required for implementation can impact productivity, which can also affect commercial viability.

Accidents and health

The implementation of new technologies and solutions can present potential risks and hazards. For example, autonomous vessels may increase the risk of cyberattacks or technical malfunctions, which could result in accidents or other safety issues (Zhou et al., 2021). The use of LNG as a fuel source may also pose risks, such as leaks or explosions. Additionally, the installation of new equipment or systems may require specialized skills and training, which can impact worker health and safety.

Social and environmental impact

The implementation of advanced shipping solutions and carbon dioxide reduction measures can have significant social and environmental impacts. For example, the use of LNG as a fuel source can reduce greenhouse gas emissions, but may also contribute to local air pollution (Lee et al., 2020). Additionally, the implementation of new technologies and solutions can impact local communities, such as through increased noise or disruption of traditional fishing or shipping activities.

Regulatory compliance

Many carbon dioxide reduction measures and advanced shipping solutions are subject to regulations and standards, which can result in penalties or fines if companies fail to comply (Serra & Fancello, 2020). Ensuring compliance can add an additional layer of complexity and cost to implementing these solutions. The impacts and costs related to the implementation of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry can be significant. These challenges require careful consideration and planning to ensure that the

benefits of these solutions are balanced against their costs and potential risks. By addressing these challenges, the industry can move towards a more sustainable and efficient future.

Carbon Reduction Awards and Incentives

Carbon reduction awards and incentives are initiatives designed to encourage and reward shipping companies that implement measures to reduce their carbon emissions. These awards and incentives can take many forms, such as tax breaks, grants, subsidies, or recognition programs, and are often offered by governments, industry associations, or non-governmental organizations (Villena & Dhanorkar, 2020). In the context of this thesis, carbon reduction awards and incentives are relevant because they can provide a powerful motivator for shipping companies to adopt carbon reduction measures and advanced shipping solutions. By offering tangible benefits to companies that implement these solutions, awards and incentives can help to offset the costs and risks associated with the implementation of these measures, making them more attractive to companies. For example, some governments offer tax breaks or subsidies to shipping companies that invest in new, more fuel-efficient ships or retrofit existing ships with new technologies to reduce emissions. Industry associations and non-governmental organizations may offer recognition programs or awards to companies that demonstrate leadership in sustainability and carbon reduction (Villena & Dhanorkar, 2020). Carbon reduction awards and incentives can play an important role in promoting the adoption of carbon reduction measures and advanced shipping solutions, helping to accelerate the transition to a more sustainable and efficient maritime industry.

Goal of the Thesis

The goal of the thesis is to analyze the challenges and opportunities associated with the implementation of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry, with a focus on the impact on efficiency and productivity. The research problem is that while these solutions offer significant benefits in terms of sustainability, they also present challenges that can impact the profitability and competitiveness of shipping operations. The thesis aims to create knowledge that can help to better understand the problem and develop strategies to address these challenges, ultimately contributing to a more sustainable and efficient maritime industry. The research will be narrow, focused and realistic, drawing on existing

literature and expert interviews to provide a comprehensive analysis of the issue.

The thesis may help to reduce the cost and create benefits for various stakeholders in the maritime industry by creating a better understanding of the challenges and opportunities associated with the implementation of carbon dioxide reduction measures and advanced shipping solutions. By analyzing the underlying causes and nature of the problem, the thesis can identify strategies to address the challenges and improve the efficiency and productivity of shipping operations. For shipping companies, the thesis can provide insights into the costs and benefits of implementing different carbon dioxide reduction measures and advanced shipping solutions. By understanding the potential impacts on efficiency and productivity, companies can make informed decisions about which solutions to invest in and how to implement them in a way that minimizes disruption to operations. For policymakers, the thesis can provide guidance on how to develop regulations and standards that encourage the implementation of carbon dioxide reduction measures and advanced shipping solutions while also addressing the challenges associated with these solutions. By understanding the trade-offs between sustainability and efficiency, policymakers can develop policies that balance the needs of different stakeholders. For the wider society, the thesis can contribute to a more sustainable and efficient maritime industry, reducing the environmental impact of shipping while also promoting economic growth and development. Ultimately, the goal of the thesis is to create knowledge that can help to reduce the cost and create benefits for all stakeholders in the maritime industry, contributing to a more sustainable and prosperous future for all.

Research Questions

The research questions (RQs) of the study based on the problem statement have been formulated as follows:

RQ₁: What are the major challenges associated with the implementation of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry, and how do these challenges impact efficiency and productivity?

RQ₂: What strategies can shipping companies adopt to address the challenges associated with the implementation of carbon dioxide reduction measures and advanced shipping solutions, and how can these strategies be implemented in a way that minimizes disruption to operations?

RQ₃: How can policymakers develop regulations and standards that encourage the

implementation of carbon dioxide reduction measures and advanced shipping solutions, while also addressing the challenges associated with these solutions and balancing the needs of different stakeholders in the maritime industry?

Chapter 2: Literature Review

The maritime industry has been under increasing pressure to reduce its carbon footprint and adopt sustainable practices. In this context, there are several theories and literature that can guide the work of the thesis related to carbon dioxide reduction measures and advanced shipping solutions. The theory of sustainable development provides a framework for understanding the importance of balancing economic, social, and environmental objectives in the maritime industry. The literature on corporate social responsibility emphasizes the importance of ethical behavior and accountability, while the resource-based view of the firm suggests that firms can leverage their unique resources and capabilities to create a competitive advantage in the context of sustainability. The literature on carbon markets and carbon pricing can provide insights into the economic incentives and mechanisms for reducing carbon emissions, while the best practices from other industries can offer effective strategies for adopting carbon dioxide reduction measures and advanced shipping solutions. These theories and literature can provide a comprehensive framework for understanding the challenges and opportunities associated with sustainability in the maritime industry, and can inform the development of effective strategies to achieve sustainability objectives.

Sustainable Development

Sustainable development is a well-established concept that emphasizes the importance of balancing economic, social, and environmental objectives to achieve long-term prosperity (Silvestre & Țirca, 2019). The maritime industry is a significant contributor to global carbon emissions (Oceana, 2023), and its efforts to reduce its carbon footprint can be guided by the theory of sustainable development. According to the Brundtland Report, sustainable development is the kind of development that fulfils current needs without compromising the capability of future generations to satisfy their own needs (Hajian & Kashani, 2021). This definition highlights the need for long-term thinking and planning to achieve sustainability objectives. The maritime industry's efforts to reduce its carbon footprint can benefit from the principles of sustainable development. According to a study by Rodseth et al. (2021), sustainable development is relevant to the maritime industry's efforts to reduce its carbon emissions. The authors argue that sustainable development requires a shift in thinking from a short-term focus on economic growth to a long-term perspective that considers social and environmental

objectives as well. This shift in thinking is necessary for the industry to adopt effective carbon dioxide reduction measures and advanced shipping solutions that are sustainable and can support future generations.

Wang and Wang (2022) highlight the importance of the sustainable development concept in the context of the maritime industry's efforts to reduce its carbon footprint. The authors argue that the maritime industry's carbon emissions are a significant contributor to global warming and climate change, and sustainable development can provide a framework for reducing these emissions. The authors suggest that sustainable development requires a holistic approach that considers economic, social, and environmental factors, and can guide the industry in adopting sustainable practices that reduce carbon emissions and support long-term prosperity. Furthermore, the theory of sustainable development can guide the maritime industry in identifying effective carbon dioxide reduction measures and advanced shipping solutions. According to a study by Khan et al. (2020), sustainable development can provide a framework for evaluating the effectiveness of carbon dioxide reduction measures and advanced shipping solutions. The authors suggest that sustainable development requires a focus on long-term objectives and the consideration of social and environmental factors in addition to economic factors. This approach can help the industry identify sustainable practices that reduce carbon emissions while maintaining efficiency and productivity.

The theory of sustainable development is highly relevant to the maritime industry's efforts to reduce its carbon footprint. The concept emphasizes the importance of balancing economic, social, and environmental objectives to achieve long-term prosperity. The maritime industry can benefit from the principles of sustainable development by adopting a long-term perspective and considering the social and environmental impacts of its operations (Xing et al., 2020). The concept can guide the industry in identifying effective carbon dioxide reduction measures and advanced shipping solutions that are sustainable and support long-term prosperity.

Corporate Social Responsibility (CSR)

Corporate social responsibility (CSR) refers to a company's voluntary actions to improve social and environmental outcomes beyond compliance with legal requirements (Carroll & Shabana, 2010). The concept of CSR has gained increasing attention in recent years, as companies are expected to act in the best interest of society and the environment. The maritime

industry is no exception, and there is a growing awareness of the industry's impact on the environment and the need for sustainable practices. In the context of the maritime industry, CSR can provide insights into the role of businesses in addressing social and environmental issues, and can guide companies in adopting sustainable practices and reducing their carbon emissions. For example, CSR can provide a framework for companies to engage in stakeholder dialogue and collaborate with other actors to identify and address social and environmental issues (Liu et al., 2016). This can help to build trust and credibility with stakeholders and demonstrate a commitment to sustainability. Moreover, CSR can also guide companies in adopting sustainable practices by emphasizing the importance of ethical behavior and accountability. This can involve a range of activities, such as reducing carbon emissions, improving working conditions for employees, and supporting local communities (Carroll & Shabana, 2010). For instance, companies can adopt policies to reduce their carbon footprint by improving energy efficiency and using alternative fuels, or by implementing measures to reduce waste and increase recycling.

CSR can also help companies to manage risks associated with sustainability issues. For example, companies that do not take action to address their carbon emissions may face reputational and financial risks as stakeholders become more aware of the environmental impact of the industry (Matten & Moon, 2008). By adopting sustainable practices and engaging in CSR activities, companies can mitigate these risks and demonstrate a commitment to long-term sustainability.

Resource-Based View

The Resource-Based View (RBV) of the firm provides a perspective on how companies can achieve sustainable competitive advantage through the adoption of innovative and sustainable practices. The theory suggests that firms can leverage their unique resources and capabilities to create a competitive advantage that is difficult for competitors to replicate (Valaei et al., 2022). In the context of the maritime industry, the RBV theory can be used to identify the specific resources and capabilities that can provide a competitive advantage in adopting carbon dioxide reduction measures and advanced shipping solutions. Several studies have applied the RBV theory to analyze the sustainable practices of firms in different industries. For example, Li et al. (2021) investigated the relationship between sustainable practices and competitive advantage in the Chinese automobile industry. The study found that firms that implemented

sustainable practices such as product innovation, green supply chain management, and environmental management had a higher level of competitive advantage compared to firms that did not implement such practices. Similarly, several studies have applied the RBV theory to analyze sustainable practices in the maritime industry. For instance, Zameer et al. (2022) conducted a study on the relationship between green innovation and competitive advantage. The study found that green innovation positively influenced the competitive advantage of firms through the development of new technologies and services that reduce carbon emissions.

Moreover, the RBV theory can also be used to identify the unique resources and capabilities that can provide a competitive advantage in the context of the maritime industry's efforts to adopt carbon dioxide reduction measures and advanced shipping solutions. The adoption of new technologies such as alternative fuels, renewable energy, and digitalization can provide a competitive advantage in terms of reducing carbon emissions and enhancing efficiency and productivity (Song et al., 2022). In addition, the development of sustainable supply chain management practices, such as green procurement and logistics, can also provide a competitive advantage in terms of reducing the environmental impact of maritime operations (Paltsev et al., 2021).

Carbon Markets and Carbon Pricing

The literature on carbon markets and carbon pricing has gained significant attention in recent years due to the pressing need for reducing carbon emissions to mitigate climate change. A carbon market is a system that creates a monetary value for carbon emissions, while carbon pricing is the imposition of a tax or cost on carbon emissions. This approach creates an economic incentive for companies to reduce their carbon footprint and adopt sustainable practices that are cost-effective (Murray et al., 2018). Hao et al. (2020) examined the impact of carbon pricing on the maritime industry and found that it can serve as a catalyst for reducing emissions. The authors suggested that a carbon pricing mechanism can provide the industry with the right incentives to invest in low-carbon technologies and practices, which can lead to long-term cost savings. The study also highlighted the need for clear regulations and policies to guide the implementation of carbon pricing in the maritime industry.

Another study by Bohringer et al. (2021) explored the potential impacts of carbon pricing on the shipping industry's competitiveness. The authors found that the implementation of carbon

pricing policies could lead to some market disruption, but overall, it could create opportunities for the industry to innovate and adapt to low-carbon technologies. The study emphasized the importance of designing carbon pricing policies in a way that balances the need for emission reductions with economic competitiveness. Furthermore, the International Maritime Organization (IMO) has developed a plan to reduce greenhouse gas emissions from the shipping industry by 50% by 2050 compared to 2008 levels, and the implementation of carbon pricing policies is seen as a key mechanism to achieve this goal (IMO, 2018). The IMO has also introduced a mandatory carbon intensity reduction framework, which requires all ships to comply with specific energy efficiency standards (IMO, 2018). The framework is designed to incentivize the industry to adopt low-carbon technologies and practices and can provide a foundation for the implementation of carbon pricing policies in the future. The implementation of carbon pricing policies can provide a catalyst for the industry to adopt sustainable practices that are cost-effective and create long-term cost savings. Clear regulations and policies are necessary to guide the implementation of these policies and ensure a balance between emission reductions and economic competitiveness.

Best Practices

The maritime industry is facing increasing pressure to reduce its carbon footprint and adopt more sustainable practices. In this context, learning from best practices in other industries can be valuable for the maritime sector to identify successful strategies and avoid potential pitfalls. The aviation industry has been working on reducing its carbon footprint for several years, and its experiences can provide valuable insights for the maritime industry. One approach that the aviation industry has taken is investing in the development of biofuels, which has the potential to significantly reduce carbon emissions. Studies have shown that the use of biofuels in aviation can result in up to 80% reduction in carbon emissions compared to traditional jet fuel (Olsen et al., 2020). The maritime industry could potentially adopt this approach by investing in the development of sustainable biofuels for ships.

Another approach taken by the aviation industry is to optimize aircraft operations and reduce fuel consumption. For example, airlines can optimize flight paths to reduce fuel consumption and emissions. This approach has been shown to be effective, with studies indicating that optimizing flight paths can result in fuel savings of up to 5% (Ma et al., 2021).

The maritime industry could potentially adopt a similar approach by optimizing shipping routes and reducing speeds to minimize fuel consumption and emissions.

The automotive industry has also made significant progress in reducing its carbon footprint, and its experiences can provide valuable insights for the maritime industry. One approach that the automotive industry has taken is to shift towards electric vehicles. Electric vehicles have the potential to significantly reduce carbon emissions, as they do not emit any pollutants from their tailpipes. The maritime industry could potentially adopt a similar approach by investing in electric ships, which can significantly reduce emissions compared to traditional ships (Wang et al., 2022). The automotive industry has also focused on improving the efficiency of combustion engines. One approach is through the use of hybrid technology, which combines an electric motor with a conventional combustion engine. This approach has been shown to be effective, with studies indicating that hybrid vehicles can reduce fuel consumption and emissions by up to 30% compared to traditional vehicles (Wang et al., 2022). The maritime industry could potentially adopt a similar approach by investing in hybrid ships that combine electric and traditional power sources.

In addition to these strategies, both the aviation and automotive industries have also implemented initiatives to reduce waste and increase recycling (Agrawal et al., 2021). For example, airlines have implemented recycling programs for inflight waste, while the automotive industry has focused on improving the recyclability of vehicles. These initiatives can be valuable for the maritime industry to adopt as part of its sustainability efforts. The best practices from the aviation and automotive industries can provide valuable insights for the maritime industry in adopting carbon dioxide reduction measures and advanced shipping solutions. The experiences of these industries demonstrate the effectiveness of investing in sustainable biofuels, optimizing operations to reduce fuel consumption, shifting towards electric power sources, and implementing waste reduction and recycling initiatives.

Carbon Dioxide Reduction Measures

The maritime industry is responsible for a significant portion of global carbon dioxide emissions, and reducing its carbon footprint is critical for achieving global climate targets (Oceana, 2023). Some common carbon dioxide reduction measures in the maritime industry are as follows. Slow steaming is used because reducing the speed of ships can significantly reduce

fuel consumption and carbon emissions. By sailing at a slower speed, ships can reduce their fuel consumption by up to 30% (Psaraftis & Kontovas, 2015). Improved hull design refers to optimizing hull design, including hull coatings. It can reduce drag and improve fuel efficiency, resulting in lower carbon emissions (Elkafas et al., 2021). Energy-efficient technologies can be adopted such as LED lighting and high-efficiency motors. They can reduce energy consumption and carbon emissions. Alternative fuels switching to low-carbon or zero-carbon fuels, such as liquefied natural gas (LNG), biofuels, or hydrogen fuel cells, can significantly reduce carbon emissions. Waste heat recovery refers to capturing and utilizing waste heat from engines and exhaust systems. It can improve energy efficiency and reduce carbon emissions. Onshore power supply when docked, instead of running ships' engines, can significantly reduce carbon emissions. Another strategy is capturing carbon dioxide emissions from ships and storing them in underground storage facilities. This technology is still in the early stages of development but has the potential to be an effective method for reducing carbon emissions. Improved operational practices highlight that the improved voyage planning, optimized routes, and improved cargo stowage can all reduce fuel consumption and carbon emissions. Eco-friendly ports can reduce carbon emissions by providing more efficient cargo handling and reducing the time ships spend in port (Armstrong & Banks, 2015).

Advanced Shipping Solutions

Advanced shipping solutions in the maritime industry refer to the use of innovative technologies and practices to increase efficiency, reduce emissions, and improve safety. Some examples of advanced shipping solutions are as follows. The use of advanced ship design technologies can improve the fuel efficiency of vessels, reduce their greenhouse gas emissions, and save costs. This includes features such as hull optimization, propeller design, and waste heat recovery systems. The use of alternative fuels such as liquefied natural gas (LNG), biofuels, and hydrogen can significantly reduce greenhouse gas emissions and improve air quality. LNG, for example, can reduce sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions by up to 90% (Deng et al., 2021). Electric and hybrid propulsion systems can significantly reduce fuel consumption and emissions. Electric propulsion systems use batteries or fuel cells to power the vessel, while hybrid systems combine traditional engines with electric motors (Ma et al., 2021). Autonomous and remotely controlled ships can improve safety and efficiency by reducing the

risk of human error and optimizing shipping routes. Digital technologies such as big data analytics, artificial intelligence, and blockchain can improve efficiency, reduce costs, and improve transparency in the supply chain. The automation of port operations can improve efficiency and reduce emissions by optimizing the use of resources such as cranes and vehicles (Iris & Lam, 2019). Slow steaming, the practice of reducing ship speeds can significantly reduce fuel consumption and emissions (Psaraftis & Kontovas, 2015). While this may result in longer shipping times, it can lead to cost savings and lower emissions. These advanced shipping solutions can help the maritime industry to reduce its environmental impact, improve safety, and increase efficiency and productivity.

The Concept of Efficiency

Efficiency in the maritime industry refers to the ability of a company or organization to achieve its objectives while minimizing waste, reducing costs, and maximizing productivity. In the context of shipping, efficiency can refer to the efficient use of fuel, time, and other resources to transport goods from one location to another. This can include strategies such as optimizing shipping routes, using more fuel-efficient vessels, and reducing emissions of pollutants such as carbon dioxide (Nguyen et al., 2022). Efficiency is a key concern for companies in the maritime industry, as it can have a significant impact on their competitiveness, profitability, and sustainability. By improving efficiency, companies can reduce their costs, enhance their operational performance, and increase their environmental sustainability, all of which can contribute to their long-term success.

Efficiency in the maritime industry is also closely related to productivity. Productivity refers to the amount of output generated per unit of input, such as labor, capital, and resources. In the context of shipping, productivity can be measured by the amount of cargo transported per unit of time or the distance traveled per unit of fuel consumed. Improving efficiency in the maritime industry can lead to increased productivity, which can result in lower costs and higher profits for shipping companies (Ugboma & Oyesiku, 2021). Additionally, as the industry faces increasing pressure to reduce its carbon footprint, improving efficiency can also contribute to a reduction in greenhouse gas emissions per unit of output.

The Concept of Productivity

Productivity in the maritime industry refers to the ability to efficiently and effectively utilize resources to generate maximum output while minimizing costs. It can be measured in terms of the quantity of goods or cargo moved per unit of time, the number of trips made by vessels, or the utilization of available transport capacity. The focus of productivity is to ensure that the resources available are utilized in the most efficient manner possible, while maintaining the quality of the services provided (Qingmei & Hong, 2021). This concept is especially important in the highly competitive maritime industry, where companies need to find ways to maximize their profitability while maintaining their competitiveness in the market.

The efficiency of operations and the use of technology are critical factors in improving productivity in the maritime industry. By implementing advanced technology and automation systems, such as remote monitoring and control systems, companies can optimize vessel routing and cargo handling processes to increase throughput and reduce operational costs. This approach not only improves efficiency but also ensures that companies can meet customer demands for faster and more reliable shipping services (Ghiara & Tei, 2021). As such, the focus on productivity is a critical component in the success and sustainability of companies operating in the maritime industry.

Challenges in the Implementation of Carbon Dioxide Reduction Measures

The implementation of carbon dioxide reduction measures in the maritime industry faces several challenges. One of the major challenges is the lack of a uniform regulatory framework for emissions reduction (Yu et al., 2021). The absence of consistent and globally applicable regulations can lead to a patchwork of regulations, which can make it difficult for shipping companies to plan their emissions reduction strategies. Additionally, shipping companies often operate in multiple jurisdictions, each with their own regulations, which can result in regulatory conflicts and make it challenging for companies to comply with all requirements. This regulatory complexity can increase costs and reduce the effectiveness of emissions reduction measures. Another significant challenge is the high capital cost associated with the adoption of new technologies and retrofitting of existing vessels (Wu et al., 2023). Many carbon dioxide reduction measures require significant investment in new technologies, such as alternative fuels, advanced propulsion systems, and emissions control technologies. Retrofitting of existing vessels

can also be costly, particularly for older ships that may require significant modifications to meet new emissions standards (Wu et al., 2023). These costs can be prohibitive for many shipping companies, particularly small and medium-sized enterprises, which can impede the adoption of carbon dioxide reduction measures.

The maritime industry faces challenges related to the availability and infrastructure of alternative fuels. The use of alternative fuels, such as hydrogen or biofuels, can significantly reduce emissions, but their availability and cost can be significant obstacles to adoption. The development of an infrastructure to support the production, distribution, and use of alternative fuels can also require significant investment, which may be a barrier for some companies (Ghaderi, 2020). Furthermore, the global nature of the shipping industry makes it difficult to establish consistent and reliable supply chains for alternative fuels, particularly in remote or developing regions.

Challenges in the Implementation of Advanced Shipping Solutions

One of the major challenges associated with the implementation of advanced shipping solutions in the maritime industry is the high cost of initial investment (Wu et al., 2023). The development and implementation of advanced technologies, such as alternative fuels, autonomous vessels, and advanced navigation systems, require significant financial resources. Additionally, retrofitting existing vessels with new technologies can be expensive, particularly for smaller companies with limited financial resources. As a result, many companies may be hesitant to invest in advanced shipping solutions, particularly in the absence of regulatory mandates or financial incentives. Another challenge is the potential disruption to existing supply chain and logistics operations. The adoption of advanced shipping solutions, such as autonomous vessels, may require significant changes to current operational processes and infrastructure (Kim et al., 2020). This may include modifications to ports and harbors to accommodate autonomous vessels, changes in cargo handling procedures, and adjustments to scheduling and routing systems. These changes may result in temporary disruptions to supply chain operations, which could affect the efficiency and productivity of the industry in the short term.

The lack of standardization and coordination among stakeholders can pose a challenge to the implementation of advanced shipping solutions (Yu et al., 2021). The development of new technologies and systems requires collaboration among various stakeholders, including shipping

companies, technology providers, regulators, and port authorities. However, the lack of standardization and coordination among these stakeholders can create uncertainty and complexity in the adoption and implementation of advanced shipping solutions. Additionally, the lack of clear regulatory frameworks and guidelines can further complicate the adoption of new technologies, particularly across different jurisdictions and regions.

Effective Strategies for the Challenges with Carbon Dioxide Reduction Measures

Shipping companies can adopt several strategies to address the challenges associated with the implementation of carbon dioxide reduction measures in the maritime industry. Companies can invest in research and development to explore new and innovative technologies that can reduce carbon emissions, such as alternative fuels, hybrid and electric propulsion systems, and energy-efficient design (Inal et al., 2022). This can be achieved through partnerships with academic and research institutions, as well as collaborations with other industry stakeholders. Shipping companies can improve their operational efficiency to reduce their carbon footprint. This can involve measures such as optimizing vessel speed and routing, reducing idle time in ports, and minimizing cargo loss and damage. Additionally, companies can invest in improved maintenance and retrofitting of existing vessels to enhance their energy efficiency and reduce emissions.

Shipping companies can engage in carbon offsetting programs to compensate for their carbon emissions. This can involve investing in projects that reduce carbon emissions in other sectors, such as renewable energy or forestry, to offset the emissions generated by shipping operations (Bohringer et al., 2021). Companies can also purchase carbon credits on carbon markets to offset their emissions and meet regulatory requirements. Shipping companies can adopt a range of strategies to address the challenges associated with the implementation of carbon dioxide reduction measures in the maritime industry, including investing in research and development, improving operational efficiency, and engaging in carbon offsetting programs. By adopting these strategies, companies can achieve their sustainability objectives while also maintaining their competitiveness in the global shipping market.

Effective Strategies for the Challenges with the Advanced Shipping Solutions

To address the challenges associated with the implementation of advanced shipping solutions in the maritime industry, shipping companies can adopt several strategies. Companies can establish partnerships with technology providers and research institutions to gain access to the latest technology and expertise. This can help to overcome the challenges associated with high capital costs, lack of expertise, and technological uncertainties. Collaborative efforts can also lead to the development of innovative solutions that are tailored to the specific needs of the industry (Solem et al., 2022). Companies can establish pilot projects to test and evaluate the effectiveness of advanced shipping solutions. This can help to identify potential challenges and opportunities for improvement, and provide a platform for stakeholder engagement and collaboration. Companies can also use pilot projects to showcase their commitment to sustainability and innovation, which can help to attract customers and investors.

Companies can invest in employee training and development to build expertise in the use and maintenance of advanced shipping solutions. This can help to address the challenges associated with the lack of skilled personnel and ensure that the solutions are used effectively and efficiently (Baum-Talmor & Kitada, 2022). Training and development can also help to build a culture of innovation and sustainability within the organization, which can facilitate the adoption of advanced shipping solutions and support the company's long-term sustainability goals.

Regulatory Framework for Carbon Dioxide Reduction Measures

The development of effective regulations and standards can play a critical role in promoting the adoption of carbon dioxide reduction measures in the maritime industry. Policymakers can consider a variety of strategies to encourage companies to reduce their carbon emissions, including setting emissions targets, mandating the use of cleaner fuels, and implementing carbon pricing mechanisms. In addition, policymakers can consider providing financial incentives to companies that invest in sustainable technologies and practices, such as tax credits or subsidies. To ensure the effectiveness of these regulations and standards, policymakers can engage with stakeholders in the maritime industry, including shipping companies, industry associations, and environmental groups (Yu et al., 2021). Collaboration with stakeholders can help policymakers understand the practical challenges of implementing carbon

dioxide reduction measures and develop regulations and standards that are feasible and cost-effective.

Policymakers can also leverage international agreements and frameworks, such as the International Maritime Organization's (IMO) greenhouse gas reduction strategy, to promote global cooperation in reducing carbon emissions from the maritime industry (IMO, 2018). International agreements can provide a framework for setting common emissions targets and promoting the adoption of sustainable technologies and practices across the industry. Policymakers can consider the development of a comprehensive regulatory framework that addresses all aspects of the shipping industry's carbon footprint, including vessel design and operations, shipping routes and practices, and the use of cleaner fuels. Such a framework could provide a long-term vision for reducing the maritime industry's carbon footprint and provide regulatory certainty for companies that are investing in sustainable technologies and practices.

Regulatory Framework for Advanced Shipping Solutions

Developing regulations and standards that encourage the implementation of advanced shipping solutions in the maritime industry requires policymakers to balance several competing factors, including the need to reduce carbon emissions, promote economic growth, and maintain safety and security in the industry. One strategy that policymakers can adopt is to establish clear and ambitious targets for the adoption of advanced shipping solutions, such as hybrid or electric propulsion systems (Munim et al., 2020). These targets can provide a clear signal to the industry of the direction in which policymakers want the industry to move, and can encourage investment in research and development of new technologies. Another strategy that policymakers can adopt is to provide financial incentives to companies that invest in advanced shipping solutions (Bach et al., 2020). This can include tax credits, subsidies, or other forms of financial support that reduce the upfront costs of investment in new technologies. These incentives can help to overcome the high upfront costs of investing in advanced shipping solutions, which may be a barrier for some companies.

Policymakers can also develop regulations and standards that require the use of advanced shipping solutions in certain contexts, such as in environmentally sensitive areas or in ports with high levels of air pollution. These regulations can provide a market for companies that invest in advanced shipping solutions, and can create a level playing field for companies that are already

investing in these technologies. Policymakers can work with industry stakeholders to develop voluntary agreements and standards that encourage the adoption of advanced shipping solutions. These agreements can be tailored to the specific needs of different sectors of the industry, and can be more flexible and adaptable than regulatory frameworks. By working collaboratively with industry stakeholders, policymakers can build trust and consensus around the need to adopt advanced shipping solutions, and can help to create a culture of innovation and sustainability in the maritime industry (Solem et al., 2022).

Balancing the Needs of Different Stakeholders

Policymakers must consider the needs and interests of different stakeholders in the maritime industry while making policies for carbon dioxide reduction measures and advanced shipping solutions. This requires a balance between economic, environmental, and social factors. The first step in achieving this balance is to engage in a collaborative and transparent policymaking process that includes all relevant stakeholders, including industry representatives, environmental groups, and labor unions (Solem et al., 2022). One strategy that policymakers can use to balance the needs of different stakeholders is to provide incentives for the adoption of sustainable practices (Bach et al., 2020). For example, policymakers can offer tax breaks or subsidies for companies that invest in advanced shipping solutions or implement carbon dioxide reduction measures. These incentives can encourage companies to adopt sustainable practices while minimizing the economic impact of these changes. Another strategy is to set clear and achievable targets for carbon dioxide reduction and the adoption of advanced shipping solutions. By setting specific targets, policymakers can create a framework for companies to work within and measure their progress against. This can also help to create a level playing field for all companies in the industry, ensuring that no company is unfairly penalized for adopting sustainable practices.

Policymakers can also use regulations and standards to balance the needs of different stakeholders (Yu et al., 2021). For example, regulations can set minimum standards for carbon dioxide emissions or require the adoption of specific advanced shipping solutions. These regulations can ensure that all companies in the industry are operating at a similar level and that the industry as a whole is making progress towards sustainability. Policymakers must consider the social and environmental impact of their policies. While economic considerations are

important, policymakers must also ensure that their policies do not have negative impacts on workers, local communities, or the environment. By balancing the needs of different stakeholders and considering the full range of economic, environmental, and social factors, policymakers can develop policies that encourage the adoption of sustainable practices in the maritime industry.

Gaps in the Literature

After reviewing the literature on the effect of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity in the maritime industry, several gaps can be identified. While there is a significant amount of research on the potential benefits of adopting sustainable practices in the industry, there is limited research on the trade-offs between these practices and their impact on efficiency and productivity. It is essential to understand the potential economic implications of adopting these measures, such as the potential costs and benefits associated with the adoption of these solutions. The existing literature primarily focuses on the environmental benefits of carbon dioxide reduction measures and advanced shipping solutions, with limited attention paid to their impact on operational efficiency and productivity. As a result, there is a gap in understanding how these measures can enhance the operational performance of shipping companies, which is crucial for their competitiveness in the industry.

There is a lack of research that considers the role of regulatory bodies and government policies in driving the adoption of sustainable practices in the maritime industry. While there is some literature on carbon pricing mechanisms, further research is required to understand the impact of these policies on the adoption of carbon dioxide reduction measures and advanced shipping solutions. In conclusion, there are significant gaps in the current academic literature regarding the effect of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity in the maritime industry. Addressing these gaps can improve the understanding of the potential economic implications of adopting sustainable practices, their impact on operational performance, the role of regulatory bodies and government policies, and the benefits and challenges for the enterprises.

Chapter 3: Methodology

Research Design and Approach

In this study, a qualitative research design will be used to investigate the effect of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity in the maritime industry. Qualitative research allows for an in-depth exploration of the research topic (Haven & Van Grootel, 2019) and provides a comprehensive understanding of the factors that influence the effectiveness of carbon dioxide reduction measures and advanced shipping solutions. The use of qualitative research will allow for the collection of rich and detailed data, which will help to develop a nuanced understanding of the research problem.

The research approach will involve collecting data through online interviews with key stakeholders in the maritime industry, including shipping company executives, industry experts, and policymakers. The use of online interviews will allow for the efficient collection of data, as well as provide access to a geographically diverse sample of participants (Thunberg & Arnell, 2022). The interviews will be semi-structured, allowing for a flexible and open-ended approach to data collection. The researcher will develop a set of interview questions that will be used to guide the interviews, while also allowing for the exploration of emergent themes and issues that arise during the interviews.

The research design and approach adopted in this study will enable a comprehensive and detailed exploration of the effect of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity in the maritime industry. The use of a qualitative approach, combined with online interviews, will provide a rich and detailed dataset that can be used to develop insights and recommendations for shipping companies, policymakers, and other stakeholders in the industry.

Rationale for selecting online interviews

Online interviews have emerged as a popular method for data collection in recent years, especially in the wake of the Covid-19 pandemic (Jones & Abdelfattah, 2020). One of the main reasons for choosing online interviews as the data collection method for this study is their convenience and accessibility. Online interviews eliminate the need for physical travel and can be conducted from anywhere in the world with an internet connection, making it easier to reach a diverse group of participants. Additionally, online interviews allow for more flexibility in

scheduling, which can be particularly useful when trying to schedule interviews with busy professionals in the maritime industry.

Another advantage of online interviews is that they can provide a greater sense of anonymity and privacy for the participants (Thunberg & Arnell, 2022). This can be particularly important in the context of sensitive topics, such as the implementation of carbon dioxide reduction measures and advanced shipping solutions, where participants may be hesitant to share their views openly in a face-to-face interview. Online interviews can also allow participants to feel more comfortable and relaxed in their own environment, which may help to encourage more candid responses.

Online interviews also provide the opportunity to record and transcribe the interviews, which can make data analysis more efficient and accurate. With the use of recording software and transcription services, the interviews can be accurately transcribed and analyzed at a later time. Furthermore, online interviews can be conducted in a variety of formats, including video or audio-only, providing flexibility for both the researcher and participant.

Sampling Strategy

In this study, the sampling strategy used is purposive sampling, also known as judgmental sampling (Bhardwaj, 2019). This method was selected because it allows for the selection of participants who possess the knowledge and experience relevant to the research topic. The aim is to identify participants who are directly involved in the maritime industry and have experience in implementing or working with carbon dioxide reduction measures and advanced shipping solutions. Purposive sampling is considered appropriate for studies with a specific research question or hypothesis, and the researcher intends to obtain information from individuals with specific characteristics.

The participant selection criteria for this study will be based on the following factors:

Industry experience: The participants must have a minimum of five years of experience working in the maritime industry, preferably in a management or technical role.

Expertise in carbon dioxide reduction measures and advanced shipping solutions: The participants must have experience in implementing or working with carbon dioxide reduction measures and advanced shipping solutions.

Geographic location: The participants should be located in different regions of the world to ensure a diverse range of perspectives.

Language proficiency: The participants must have fluency in English, as this will be the language used during the online interviews.

Potential participants will be identified through industry associations, online professional networks, and recommendations from industry experts. The researcher will contact potential participants through email or online messaging, providing them with an explanation of the study's purpose, selection criteria, and an invitation to participate in the study.

Data Collection Method

The data collection for this study will be conducted using online interviews, which will be conducted through video conferencing platforms such as Zoom or Skype. The interviews will be structured and will consist of a series of open-ended questions related to the research objectives. The questions will be designed to elicit responses related to the impact of carbon dioxide reduction measures and advanced shipping solutions on efficiency and productivity in the maritime industry.

The interviews will be conducted with participants who meet the selection criteria, which include professionals who are currently working in the maritime industry and have expertise in the areas of carbon dioxide reduction measures and advanced shipping solutions. The interviews will be conducted in English, which is the language of communication in the maritime industry. The interviews will be audio and video recorded with the consent of the participants. The audio recordings will be transcribed verbatim, and the data will be analyzed using thematic analysis (Braun & Clarke, 2019).

To ensure the privacy and confidentiality of the participants, all data collected will be stored securely and will only be accessible to the research team. The participants will also be given the option to review their responses and withdraw their participation at any point during or after the interview.

Ethical Considerations

Ethics considerations are an essential part of any research, and it is crucial to ensure that participants' rights and privacy are protected throughout the research process. The study will

adhere to ethical guidelines set by the Institutional Review Board (IRB) and follow ethical principles of informed consent, confidentiality, and voluntary participation (Xu et al., 2020). Participants will be informed of the study's purpose, procedures, and potential risks and benefits before agreeing to participate. They will also have the right to withdraw from the study at any point without any negative consequences.

The study will obtain written consent from all participants before the online interviews. The consent form will include information on the study's purpose, procedures, potential risks and benefits, and the participant's right to withdraw from the study. The consent form will also state that all information collected during the study will be kept confidential and that no identifiable information will be included in any publications resulting from the study.

Confidentiality of the data will be maintained throughout the study. All data collected during the interviews will be stored securely on a password-protected computer. Only the research team will have access to the data, and any identifying information will be removed from the transcripts to ensure anonymity. All data will be stored securely for a period of 5 years after the completion of the study, after which it will be destroyed.

The study will also adhere to ethical guidelines for online research, including obtaining participants' consent to record the interviews and ensuring that the online platform used for the interviews is secure and encrypted to protect participants' privacy. Overall, the study will prioritize the protection of participants' rights and privacy throughout the research process.

Data Analysis Procedure

The data analysis for this study will consist of several procedures and techniques to ensure that the research questions are answered effectively. The first step will involve transcribing the online interviews to ensure that all responses are accurately recorded. The transcripts will be read multiple times to identify common themes and patterns in the data. Next, a coding system will be developed to categorize the data into relevant themes and concepts. This coding system will be reviewed and refined by the research team to ensure that it accurately reflects the data.

The data will be organized and consolidated into different categories and subcategories, and relationships between them will be identified. The analysis will also allow for the identification of any gaps in the data or themes that may require further exploration through

additional interviews or analysis.

Once the data is organized and coded, the researcher will conduct a thematic analysis (Braun & Clarke, 2019) to identify patterns and relationships within the data. This analysis will involve looking for similarities and differences within and between the categories and subcategories. The researcher will also identify any notable trends or outliers in the data that may be important for further analysis.

Finally, the researcher will use the results of the thematic analysis to draw conclusions and answer the research questions. The findings will be presented in a clear and concise manner, using quotes from the participants to illustrate key points. The researcher will also compare and contrast the findings with previous research in the field to provide context and highlight the unique contributions of this study.

Theoretical Framework

The theoretical framework of this study is centered on the Resource-Based View (RBV) of the firm (Valaei et al., 2022). This theory suggests that a firm's unique resources and capabilities can contribute to its competitive advantage, and this advantage can be sustained over time if the resources and capabilities are valuable, rare, inimitable, and non-substitutable (VRIN). The RBV theory can be applied to the maritime industry's efforts to adopt carbon dioxide reduction measures and advanced shipping solutions, which can provide a competitive advantage in the context of increasing pressure from regulatory bodies and stakeholders.

Additionally, this study will also draw upon the Corporate Social Responsibility (CSR) theory, which emphasizes the importance of ethical behavior and accountability. CSR suggests that businesses have a responsibility to address social and environmental issues and can guide the maritime industry in adopting sustainable practices and reducing its carbon emissions ((Liu et al., 2016). The combination of RBV and CSR theories will provide a comprehensive framework for analyzing the effectiveness of carbon dioxide reduction measures and advanced shipping solutions in improving efficiency and productivity in the maritime industry.

The RBV theory will inform the analysis of how companies can leverage their resources and capabilities to develop and implement carbon dioxide reduction measures and advanced shipping solutions. The CSR theory will provide insights into how businesses can act ethically and take responsibility for their impact on the environment, society, and stakeholders. This

theoretical framework will guide the research questions and data analysis to ensure a thorough examination of the effectiveness of carbon dioxide reduction measures and advanced shipping solutions in improving efficiency and productivity in the maritime industry.

Contribution of the Research

The research is expected to contribute to the existing body of knowledge by providing insights into the implementation and impact of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry. The research aims to address the gap in the literature by exploring the effectiveness of different strategies and measures adopted by shipping companies to reduce their carbon footprint, and their impact on the efficiency and productivity of the industry.

This research can provide practical guidance to shipping companies, policymakers, and other stakeholders on the implementation of carbon dioxide reduction measures and advanced shipping solutions in the maritime industry. The findings of this study can help in identifying the challenges and opportunities associated with the implementation of these measures and can provide strategies for overcoming these challenges. Additionally, the research can help in developing policies and regulations that can facilitate the implementation of sustainable practices in the industry, while balancing the needs of different stakeholders. The goodwill and reputation of the organizations working in the maritime industry will not only be dependent on their financial indicators but also on how well they contribute to the environmental protection measures and use advanced technology for shipping solutions.

Chapter 4: Data Analysis and Results

The study followed a qualitative research design and used online interviews for the data collection. The interview questions were related to the main theme of carbon dioxide reduction measures and state-of-the-art shipping solutions in the context of maritime industry. The researcher ensured that the interview questions are framed in a way that the perceptions of the interviewees could facilitate the researcher in answering the three research questions of the study. A total of ten interviews were conducted. Out of these, six interviews were conducted on Zoom, while four interviews were conducted on Skype. Five participants had an experience of more than 10 years working in the maritime industry, while the other five interviewees had an experience of more than 5 years but less than 10 years. All interviewees were experts in the knowledge of state-of-the-art shipping solutions and carbon dioxide reduction measures. The interviewees were geographically dispersed in five locations; however, it did not create any issue in the data collection because all the interviews were conducted online. The participants were fluent in English and they were also members of various professional networks and industry associations. In the presentation of themes below, the interviewees have been referred with pseudonyms such as Interviewee 1, Interviewee 2, and so forth.

Challenges in Carbon Dioxide Reduction Measures

Interviewees highlighted that in the contemporary context, cost is the major challenge in the implementation of carbon dioxide reduction measures. Due to the global super commodity cycle, there is a consistent increase in the price of all items and materials. The reduction measures require the development of a new and advanced setup. There is no doubt that the reduction measures will improve the efficiency and productivity of the maritime industry. However, these benefits will only be seen in the long run. In the short-run, the senior management is reluctant in allocating sufficient resources for the environmental protection and sustainability agenda. They are fighting the battle of survival and even finding it difficult to maintain the current count of workforce. Interviewee 3 said, *“If you don’t have the money for the salaries, staff cost, and operational expenses, how can you think about the new initiatives such as carbon dioxide reduction measures?”*

Some interviewees were still hopeful about the sustainability initiatives. They highlighted that the climate change has ruined the life in many countries in the form of natural disasters,

earthquakes and floods. Therefore, the reduction measures are not an agenda item that could be delayed anymore. These measures should be implemented in the maritime industry on an urgent basis. Interviewee 5 commented, *“Since the resources of the individual organizations are limited in tough economic conditions, the professionals in the maritime industry should work together and seek financial resources from potential investors and crowd funding platforms. We have a significant contribution to carbon emissions, and we cannot overlook our responsibility in this regard.”*

Interviewees also mentioned that there is a lack of standardization regarding how the maritime industry should proceed to carbon dioxide reduction measures. Since the interviewees were geographically dispersed, it became evident that they were thinking about different strategies. These variations in the thinking patterns make the collaboration at the global level extremely difficult. The interviewees highlighted that in their countries, there is no regulatory framework developed for carbon dioxide reduction measures in the maritime industry. According to Interviewee 1, *“a regulatory framework is needed not just to enforce carbon dioxide reduction measures but also to give incentives to those organizations that are implementing reduction measures.”* Interviewees mentioned that the corporate social responsibility is now a critical area of consideration in the maritime industry as well and many industries also publish CSR reports highlighting their social contributions. However, due to the absence of a regulatory framework, there is no sense of urgency in the maritime industry, and CSR agendas are governed by the strategic directions of individual organizations.

Interviewees highlighted that the increased use of renewable sources of energy can significantly reduce carbon emissions in the maritime industry. However, the alternative sources of energy for the industry are biofuels and hydrogen. These are highly expensive sources. Interviewee 10 mentions, *“When the organizations are facing sustainability issues, who, in the senior management will approve the use of hydrogen and biofuels?”* Interviewees emphasized the intervention of the governments to promote the use of alternative fuels. If the taxes and duties are reduced on the consumption of these fuels, an increased level of adoption may be observed in the maritime industry that will contribute significantly to carbon dioxide reduction measures. Interviewee 7 commented, *“The businesses have an increased pressure from environmental protection organizations and groups to implement carbon reduction measures. But what the government is doing? Shouldn't it incentivize this activity and give discounts on alternate fuels?”*

Interviewees also explained that carbon reduction measures require the development of an entirely new infrastructure. For example, renewable energy systems require a different infrastructure to that of conventional sources. Therefore, the professionals in the maritime industry are fearful of taking up this huge challenge. If the tasks are not executed as expected, they might be blamed for incurring huge losses to the organization. Interviewee 4 said, *“The company with which I am associated has competent professionals who have good plans and initiatives for carbon dioxide reduction measures. However, they are not willing to take the ownership and responsibility due to a huge infrastructure cost associated with this project.”*

Interviewees highlighted that the issue of carbon emissions is a global issue and maritime industry in one country cannot resolve this issue. For example, if one country uses alternative fuels, the practice needs to be replicated in all countries and regions where the ships and vessels will be entering. If other countries do not use alternative fuels, a reliable supply chain cannot be established and the benefits of reduction strategy cannot be obtained. Interviewee 6 commented, *“Ok. I accept your argument that the maritime industry should consider carbon dioxide reduction measures. But how far can I go. My company? My country? What about other countries, other regions? If they do not introduce any measures, there is no use of our efforts. The ships have a cross-border operations. They travel to different world destinations. Therefore, the efforts of a single company or country would not be meaningful.”*

Challenges in Advanced Shipping Solutions

Interviewees highlighted that the use of advanced shipping solutions is a good idea for the maritime industry but a huge resistance to change may be experienced in this process. It is because advanced solutions such as advanced navigation, autonomous vessels, scheduling systems, routing systems, and cargo handling systems require a comprehensive business process reengineering. Business processes in the maritime industry and the companies take a long time to establish and extensive training is conducted to train the workforce regarding these business processes. If there is a paradigm shift in these processes for using the advanced technology, the workers might not be comfortable in the adoption of new technology and they may also develop a sense of job insecurity. Interviewee 2 said, *“Advanced technology is a brilliant idea but the management also needs to consider the technology acceptance potential of the employees. The workers are tuned to performing the tasks in a certain way, and they feel burdened and stressed*

by the introduction of new technology.” Interviewee 8 did not agree with this option and described that the business entities should have a customer-oriented approach. Interviewee 8 commented, “We are in a competitive maritime industry and should always find ways to have a competitive advantage. Lower technology acceptance level of the employees is no justification of not using advanced shipping solutions. If there is something good for the customers and the planet, the companies should implement those measures.”

Similar to carbon dioxide reduction measures, the interviewees also highlighted that a high initial investment is a major barrier in implementing advanced shipping solutions. The new technology is highly expensive and retrofitting vessels with the advanced shipping solutions may not get the management approval in the current context. Interviewee 9 recommended, *“I think we should find investors and donor agencies and present to them the case of advanced shipping solutions for its impact on efficiency and productivity. It is the only way to implement these measures because the individual organizations will always have affordability issues.”*

Interviewees opined that stakeholders are not collaborating on implementing advanced shipping solutions. Due to the lack of coordination, there is no concrete development on this front. The advanced shipping solutions in the maritime industry require a lot of time, energy, and investment and this implementation is possible only when all stakeholders show their interest and contribute in the implementation process. Interviewee 5 said, *“Maritime operations involve many stakeholders including the marine services, ferries, shippers, receivers, agents, carriers, government agencies, and consumers. The technological solutions are possible only when all stakeholders advocate for the new and innovative solutions.”*

Interviewees also mentioned that the advanced shipping solutions lack standardization and different vendors claim their solutions to be the best in the world. In the absence of the best practices and global standards, it becomes difficult to benchmark those solutions and the shipping companies find it hard to justify the technological solutions to the senior management. Interviewee 8 commented, *“There is no check list and standards available regarding the new technology and advanced solutions. If such a checklist were available, we would put a checkmark against the availability of those features in the vendor’s solutions and select the best vendor by conducting a comparative analysis.”*

Interviewees also mentioned that the implementation of advanced solutions is also influenced by the regulatory restrictions in different countries. Some countries are very sensitive

regarding the autonomous and AI-based solutions. Interviewee 3 gave the examples of two advanced solutions autonomous vessels and navigation systems. These systems also pose security risks and the governments fear that these systems may also be used by the enemy countries for surveillance and tracking. Interviewee 3 related it with the use of automated drones and drone cameras. The technology was very promising and embraced by many countries in different fields and industries. However, the security concerns have also been raised regarding the use of drones and in some jurisdictions and areas, it is prohibited to use drones and drone cameras. The same is the case with advanced shipping solutions. The ships enter into different ports and port authorities in some countries may question the use of advanced shipping solutions.

Effective Strategies for Carbon Dioxide Reduction Measures

When interviewees were asked to tell the effective strategies that could overcome the challenges related to carbon dioxide reduction measures, they presented various strategies and recommendations. One of the recommendations given by Interviewee 7 was to participate in carbon emission reduction programs. These programs have been introduced in various countries and international environmental agencies have also launched such initiatives. Interviewee 7 said, *“When you become part of these programs, they help you in reducing your carbon footprint. They visit your facility and give you advice based on their experience. These entities are also supported by various investors and donor agencies and they also give you monetary rewards and incentives.”* Interviewee 10 recommended that the shipping companies should adopt a phase wise approach of carbon dioxide reduction measures. The interviewee gave example from another industry and named IKEA, which is a furniture retailer. The company has established a target of net zero carbon emission by 2030, and there are several other year-wise targets to reduce carbon emissions. Interviewee 10 said, *“These companies are success stories that should also be followed in the maritime industry. We cannot achieve net zero carbon emission in one month. It will take time. If our targets are over-ambitious, we will never achieve it. But if we adopt a phase-wise approach, we will not only achieve those targets, but its positive results will also be seen in the efficiency and productivity of the workforce and shipping companies.”*

Interviewees highlighted that the shipping companies and port authorities are not spending enough financial resources for research and development. Carbon emission reduction is now a complete science and many universities now offer degree courses in environmental

science and sustainability. Due to the higher cost associated with these measures, it is crucial to invest heavily in research and development. In the absence of an extensive research, the shipping companies will introduce measures that may prove counterproductive. Interviewee 1 said, *“There are no standards available, no best practices established, if we believe the perspective of one or two managers, we will take a big risk. We cannot afford to go wrong.”*

Interviewee 6 mentioned regarding the shipping companies to implement carbon dioxide reduction measures in the near future and said the companies should raise awareness regarding these solutions in the workforce. It is because the knowledge of some of the factors may be required immediately and at that time, it might not be possible to train the workforce. Interviewee 6 commented, *“I give you the example of an energy-efficient design of ships. It can significantly reduce carbon emissions. But the ships are not procured frequently. However, when the procurement process is initiated, the workforce should be well-trained so that the new ship is developing by using an energy-efficient design and the developers could contribute to carbon reduction measures.”* Similarly Interviewee 4 gave the examples of hybrid systems that save energy and reduce emissions. However, retrofitting these systems in the existing vessels is either not possible or highly costly. Therefore, the workforce should be knowledgeable about these factors of reducing emissions so that when this knowledge is needed, the relevant tasks could be performed efficiently.

Effective Strategies for Advanced Shipping Solutions

Interviewees indicated that due to the higher cost associated with the implementation of advanced shipping solutions, the shipping companies should conduct pilot testing before implementing those solutions. Interviewee 2 talked about alternate fuels. These fuels should first be used in parallel to the conventional fuels to analyze the benefits in relation to the cost of implementation. Interviewee 2 also mentioned the advanced navigation systems. These navigation systems should be tested in selective shipping operations to know if they work and are allowed in different countries and jurisdictions. Interviewee 2 commented, *“In advanced shipping solutions, pilot-testing is the key. You don’t have enough successful models, so you cannot jump start. You first need to evaluate if a given solution is workable and can provide benefits in the long run.”*

Interviewees also recommended that shipping companies and port authorities should build partnerships with the technology vendors. The technology providers may not have an adequate knowledge regarding the specific requirements of the maritime industry concerning advanced shipping solutions. The maritime professionals can tell them their issues in shipping and they could then make customized solutions to address those needs. The collaboration could also reduce the cost of implementation because the customized solutions can also consider the cost factor. Interviewee 9 said, *“Tech people are expert in technology but they don’t know the maritime industry equally well. Maritime industry is different in that the shipping solutions are cross-border and different countries and jurisdictions are involved. So, we should sit together to build the state-of-the-art solutions.”*

Interviewees explained that one of the reasons of a slower progress on advanced shipping solutions is that they are based on highly sophisticated technologies. The current workforce is not well-trained in using this technology. If the management decides to implement these shipping solutions, the technology providers will configure the systems and then only be available for support services. The systems then have to be operated by the ground staff, and the employees will require extensive training in using those systems. Interviewee 5 mentioned that in some of the cases, the shipping companies may also have to send the workforce on international training to learn the usage of new tools. Therefore, this implementation can become quite expensive overall, and the management should consider these factors. Interviewee 7 recommended, *“Instead of sending all the department on an international training, it is better to send two or three people and make them master trainer. These trainers can then train other workforce in the shipping companies.”*

Policymaking for Carbon Dioxide Reduction Measures

Interviewees mentioned about carbon markets that have been introduced in various industries and jurisdictions. Interviewees recommended that incentives on reducing carbon emissions should be introduced in the maritime industry globally that will increase the attention of the shipping companies towards these measures. Interviewee 3 highlighted that policymakers should highlight the climate change outcomes such as the floods and extreme weather conditions so that the maritime industry could make the reduction measures a priority agenda. Interviewee 3 said, *“Floods are being observed in different countries, Extreme weather conditions are reported*

in many states. These news should be projected by the policymakers on the local and international media to make the people realize the seriousness of the issues.”

Interviewees were of the opinion that the incentives alone are not sufficient for reduction measures and policymakers should also include mandatory clauses in the policies and procedures. There should be both positive and negative reinforcements to accomplish this objective. Interviewees recommended that the policy clauses should make it mandatory for the shipping companies to reduce their carbon footprint to a certain percentage each year. If they do not comply with these regulations, they should be penalized for it. Interviewee 2 said, *“Why my shipping company should only focus on reduction measures when other companies have no such plans? It’s not going to work unless there is a system of benefits and penalties developed by the policymakers.”*

Interviewees mentioned that the policymakers should also enforce the implementation of international agreements in their countries. Currently, there is a lack of standardization in adopting carbon dioxide reduction measures and the best practices can evolve if the policymakers in different countries implement international agreements concerning the maritime industry. These agreements can then become universal standards to be followed by all nations. Interviewee 9 recommended, *“The policymakers should develop specific policies for individual carbon reduction measures. For example, there should be a separate policy for vessel operations, another policy for alternate fuels, and yet another policy for shipping routes.”*

Interviewees also highlighted the need for continuity in policies and procedures regardless of the changes in the governments and political parties. Interviewees expressed their concerns that some political parties are highly vocal about carbon dioxide reduction measures whereas others overlook these initiatives. Interviewee 10 said, *“If there are continuities in the policies at the national level, the shipping companies will be more comfortable in investing in carbon dioxide reduction measures.”*

Policymaking for Advanced Shipping Solutions

Interviewees described that regarding the advanced shipping solutions, the knowledge of the maritime industry professionals is limited at present. Due to the limited knowledge, the business managers set ambitious targets, and at the end, their efforts are not materialized. The targets such as navigation systems, hybrid systems, and alternate fuels are large-scale projects

and the policymakers should emphasize on the research and development activities for the proper implementation of these solutions. Interviewee 1 said, *“The policies should not merely advocate advanced shipping solutions but also more and more research. These are quite expensive solutions and the decision-making should be backed up by intelligent data.”*

Interviewees highlighted that the policy clauses should also ask the technology organizations to build the solutions in collaboration with the maritime industry because the industry faces new challenges and issues. The technical expertise is not enough to develop those solutions. The technology vendors should also have a good level of understanding of the tools and technology needed in the maritime industry. Interviewee 4 said, *“It’s not one size fits all. The maritime industry has its own issues and we, the maritime professionals, know the exact pain points. Therefore, technology vendors should discuss with us before developing any solution.”*

Interviewees mentioned that policymakers before making any regulations should also review international agreements, and their policies should not contradict with international agreements. This issue of contradiction is particularly sensitive in the maritime industry because due to cross-border operations, the laws of destination countries also apply to the shipping companies. Therefore, the global compliance of the policies should always be considered. Interviewee 6 commented, *“In the maritime context, we don’t live in isolation. We travel throughout the world. Therefore, our policies should also be aligned with the global standards.”*

Interviewees recommended that the policymakers and regulators should also hold annual conferences and functions. In these exhibitions, the advanced shipping solutions should be presented by the technology vendors. The vendors should also mention the cost and benefits of each solution. Maritime professionals can evaluate these solutions during the exhibition. Moreover, annual awards should also be given to those shipping companies and port authorities that were successful in implementing advanced shipping solutions. Interviewee 8 said, *“It will prove to be a brilliant initiative on the part of the policymakers. The success stories will become known to all maritime industry professionals. These forums will also promote collaboration and advanced shipping solutions will be implemented by collective wisdom and working together.”*

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