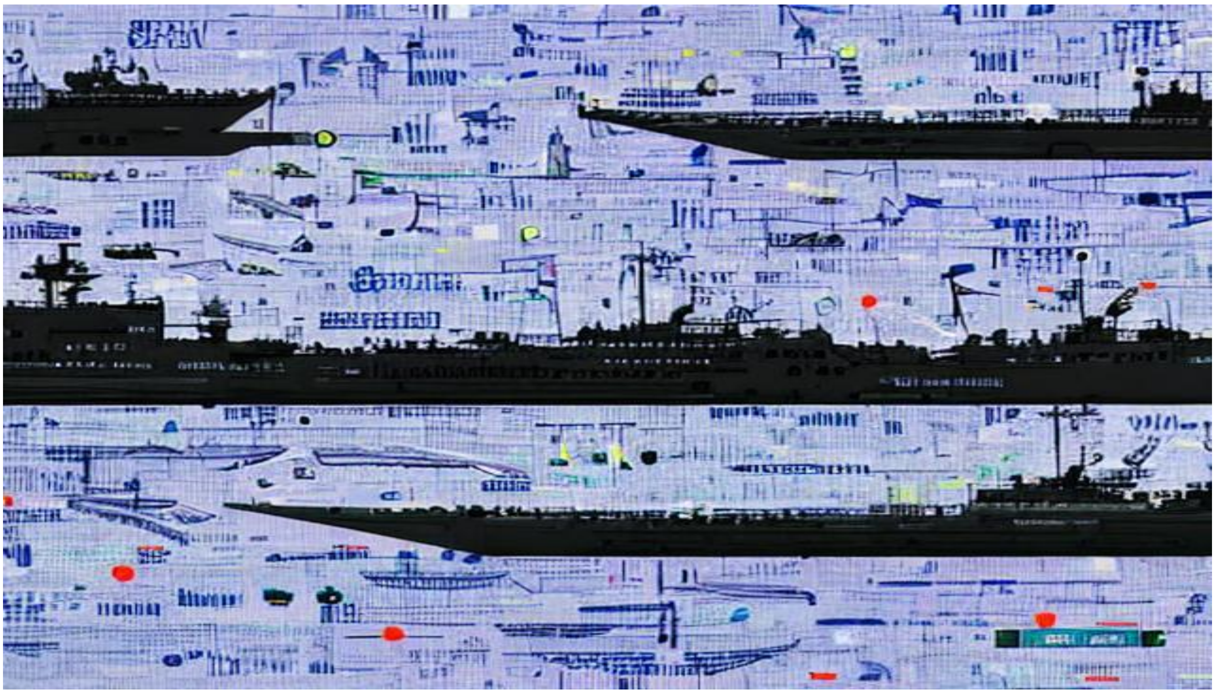

The added value from AI on sustainable business models

How AI improves economic and environmental sustainability in the shipping industry

Bachelor thesis for International Logistics Program

ARVID HULTMAN
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DEPARTMENT OF MECHANICS AND MARITME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
An AI generated picture created by the prompt "Army of ships taken over by artificial intelligence".

Department of Mechanics and Maritime Sciences
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PREFACE

As students of the International Logistics program at Chalmers University of Technology, we had the opportunity to delve into the world of shipping and explore the ways in which new technologies can enhance the industry's efficiency and sustainability. This thesis is the culmination of an educative journey, during which we were able to study some of the leading companies in the shipping industry and gain insights into their operations.

The International Logistics program provided us with a comprehensive education in logistics and supply chain management, as well as exposure to various cutting-edge technologies. The program's courses on sustainability and global perspectives have equipped us with the skills and knowledge necessary to tackle some of the world's most pressing challenges.

The scope of this thesis was to explore the value that AI adds to the global shipping industry and to inspect the prospects for AI integration in the Swedish shipping industry. We had the privilege to work with one of the industry's most innovative companies, the Swedish Maritime Administration, who generously shared their expertise and insights with us.

We are grateful for the support and guidance of our supervisor, who provided us with invaluable feedback throughout the research process. We are also thankful for the contributions of the companies who participated in this study and shared their knowledge and experiences with us.

We hope that this thesis serves as a useful resource for those interested in the shipping industry and the ways in which AI can be leveraged to promote sustainability and efficiency.

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SAMMANDRAG

Denna rapport utforskar möjligheterna för artificiell intelligens (AI) att påverka affärsmodeller inom sjöfarten genom att skapa värde och bidra till hållbarhet. I rapporten undersöks även den svenska sjöfartsindustrins framtid angående AI. Rapporten är baserad på en litteraturstudie från internationella källor samt en fallstudie baserad på intervjuer.

Nyckelord: Artificiell intelligens, AI, affärsmodeller, hållbara affärsmodeller, värde, sjöfart, AIS, ekonomisk hållbarhet, ekologisk hållbarhet

The added value from AI on sustainable business models
How companies use AI to create value in the Swedish shipping industry

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ABSTRACT

This bachelor thesis explores the added value of Artificial Intelligence (AI) on sustainable business models and its prospects within the Swedish shipping industry. The study focuses on identifying the potential benefits and challenges of integrating AI technology into shipping practices to make them more economic and environmentally sustainable. The research is based on a literature review that includes sources from various countries, while the case study delimits the analysis to the Swedish shipping industry. The study examines the benefits of AI in optimizing vessel operations, reducing fuel consumption, and predicting maintenance of equipment. Additionally, challenges such as regulatory compliance, technological barriers, and stakeholder collaboration are addressed. Drawing on the literature review and the case study, the paper shows that AI has the potential to add value to sustainable business models in the industry by improving vessel performance, reducing carbon emissions, and promoting overall economic and environmental sustainability.

Keywords: AI, Artificial intelligence, Added value, Sustainable business models, shipping, AIS, economic sustainability, environmental sustainability,

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ACRONYMS AND TERMINOLOGY

AI	Artificial Intelligence
AIS	Automatic identification system
ECDIS	Electronic Chart and Display Information System
ANN	Artificial Neural Network

1. INTRODUCTION

The shipping industry is an essential contributor to the global economy, with over 80% of world trade being carried by sea (UNCTAD, 2022). However, the industry is also a significant source of greenhouse gas emissions, which contribute to climate change and environmental degradation. According to the European Commission (EC), the shipping industry is responsible for approximately 3% of global greenhouse gas emissions, and this figure is expected to increase in the coming years (EC, 2022).

In response to these challenges, the shipping industry has been exploring various sustainable business models to reduce its environmental impact. Sustainable business models involve creating value in a way that considers environmental, social, and economic factors (Bocken et al., 2016). Sustainable business models have the potential to not only reduce environmental impacts but also improve financial performance and competitiveness (Boons et al., 2013).

One of the ways in which the shipping industry can achieve sustainable business models is by incorporating AI-based solutions. AI has the potential to revolutionize the industry by optimizing operations, improving efficiency, and reducing costs (McKinsey Global Institute, 2018). AI-based solutions can also help shipping companies to achieve sustainability goals by reducing fuel consumption, optimizing shipping routes, and minimizing environmental impact (Frackiewicz, 2023).

While AI has shown promise in improving sustainable practices in the shipping industry, there are still challenges to overcome. Some of the main challenges are the lack of understanding, as well as regulatory and legal constraints, which can hinder the implementation of AI-based solutions (A business developer at the Swedish Maritime Administration, personal communication, March 30, 2023). Furthermore, there are concerns about the potential displacement of jobs and the ethical implications of relying on AI in decision-making processes (EC, 2022).

In this study, we aim to explore the use of AI by conducting a literature review as well as a case study of companies that have implemented AI-based solutions in their operations. Our research will focus on how these solutions contribute to the development of sustainable business models by improving economic and environmental sustainability. We will review existing literature on the topic to provide a broader understanding of the potential of AI for sustainable shipping.

The results of this study aim to provide insights into how shipping practices can be improved by implementing AI-based solutions to achieve more sustainable business models. The findings will be of interest to stakeholders in the shipping industry, policymakers, and researchers in the fields of sustainable business and AI.

1.1 Background

Given its importance to the global economy, the shipping industry has not been immune to the rising emphasis on sustainability, with a surge in publications on sustainable shipping (Shin et al, 2018). Simultaneously, the concept of sustainable business models (SBM) has gained traction in strategic management research. At the same time, the maritime sector has focused more on digitalization. Among new technologies for digitalizing and improving business processes and operations, artificial intelligence (AI) has promised unparalleled levels of efficiency, coordination, and transparency.

While the benefits of AI integration in the shipping industry seems to be clear intuitively, it is mostly based on theory and speculation. This study was employed to find empirical evidence on the value that AI can add by improving economic and environmental sustainability. Upon preliminary research, it was surprising to find a lack of AI implementation in the Swedish shipping industry. Therefore, the study is needed to explore the prospects of integrating AI-based technology in Sweden.

While these three domains —sustainable shipping, sustainable business models, and AI-based technologies — have been studied in maritime and logistics studies, few articles have looked at how they interact. There is a need for further research to understand the full potential of AI in this context, as well as the challenges that need to be addressed to enable its effective implementation. This report aims to address this gap in research by exploring the interrelationship between AI-implementation and improved sustainability. The purpose of this is to contribute to the momentum of leveraging technology to boost prosperity in the shipping industry.

1.2 Aim of the study

The aim of this report is to explore the added value of AI technology on sustainable business models in the shipping industry. In other words, how AI improves economic and environmental sustainability in shipping practices. Through a literature review and a case study research design, the study will explore how companies use and can use AI-based solutions to add value to their company by improving their economic and environmental sustainability. Furthermore, it will explore the prospects of implementing AI-based solutions in the Swedish shipping industry. The purpose of the study is to educate and create a better understanding of AI and how it can be used to lower the impact on the environment and to save money.

1.3 Research questions

1. How does AI add value in terms of economic and environmental sustainability?
2. What are the prospects for adding value through AI integration in the Swedish shipping industry?

1.4 Delimitations

The research paper is looking at the added value of AI implementation on sustainable business models in the shipping industry. Sustainable business models consist of three main elements: economic, environmental, and social sustainability. Due to its subjectivity and difficulty to analyze, the impact that AI has on social sustainability will not be looked at. Therefore, the study delimits sustainable business models to two of its elements: economic, environmental sustainability.

Given the expansiveness of the possible scope of the project, this report is not designed to be exhaustive; rather, it presents some of the most important aspects for AI implementation in the shipping industry. The possibilities for AI implementation in shipping processes are wide-ranging. Thus, the most researched areas of AI integration will be examined to avoid being too speculative and to provide a more focused analysis. The report will present the current ways of AI implementation and utilization in the global shipping market, and how it leads to business models in the industry to become more sustainable. This is followed by a forward look into the Swedish shipping industries ambitions and challenges of implementation in the future. This report is delimited to the Swedish shipping industry regarding the case study. Although, the literature used is not limited to any country of origin.

2. THEORY

In this chapter, a theoretic basis will be laid out to provide the information needed to understand the different concepts that will be discussed in the thesis.

2.1 The maritime industry and the environment

The shipping industry plays a crucial role in global trade and commerce, but it also poses significant environmental challenges. This subchapter will summarize the environmental harms associated with the shipping industry:

Air Pollution and greenhouse gasses: Shipping vessels primarily rely on the use of fossil fuels, such as heavy fuel oil, which emits large amounts of air pollutants. These pollutants are mainly greenhouse gasses (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), along with other pollutants such as sulfur oxides (SO_x) and particulate matter (PM) (European Maritime Safety Agency, n.d.). Shipping emissions contribute to air pollution, climate change, and adverse health effects in coastal areas and port cities The shipping industry is a major contributor to global greenhouse gas emissions. It is estimated to account for 3% of global CO_2 emissions annually (EC, 2022). The high volume of shipping activities, coupled with the carbon-intensive nature of fossil fuels used, contributes to the industry's significant carbon footprint.

Ballast Water Discharge: Ballast water, which is taken on by ships to stabilize their balance, often contains a variety of non-native species. When this ballast water is discharged into different ecosystems, it can introduce invasive species, leading to ecological disruptions and biodiversity loss (Elçiçek et al., 2013).

Oil Spills and Marine Pollution: Accidental oil spills from shipping vessels pose a severe threat to marine ecosystems and coastal habitats. Spills can result from collisions, groundings, or equipment failures, leading to immediate and long-term environmental damage. Additionally, the improper discharge of sewage, graywater, and other pollutants can further degrade marine environments (Helle et al., 2020).

Noise Pollution: The noise generated by ships, particularly from propellers and engines, can have detrimental effects on marine life. Underwater noise pollution can disrupt marine mammal communication, affect their feeding and breeding patterns, and lead to stress or even death in extreme cases (Firestone et al., 2007).

Habitat Destruction and Coastal Erosion: Ports and shipping infrastructure development can result in the destruction and alteration of coastal habitats, including wetlands and mangroves. These habitats serve as critical ecosystems, providing numerous ecological services such as coastal protection, carbon sequestration, and support for diverse marine life (Walker et al., 1998).

Addressing these environmental harms requires concerted efforts from the shipping industry, governments, and international organizations. Measures such as adopting cleaner fuels, improving vessel efficiency, implementing ballast water treatment systems, and promoting sustainable practices can help mitigate the environmental impact of the shipping industry and move towards a more sustainable future (Walker et al., 2019).

While regulatory frameworks governing emissions serve as a guiding force to promote sustainability in shipping, alternative tools are gaining traction as potential solutions to complement existing measures, such as integrating artificial intelligence.

2.2 Ship efficiency

Ship trim, draft optimization, and speed optimization are crucial elements in the pursuit of enhanced fuel efficiency and reduced greenhouse gas emissions within the maritime industry. Ship trim refers to the balance and alignment of a vessel in the water, aiming to achieve the most favorable hydrodynamic conditions. By optimizing the trim, vessels can minimize resistance and improve fuel efficiency. Draft optimization involves adjusting the ship's draft or immersion level in the water, considering factors such as cargo load, weather conditions, and navigational requirements. Proper draft optimization ensures optimal buoyancy and reduces unnecessary hull resistance, contributing to fuel savings. Additionally, speed optimization focuses on identifying the most fuel-efficient operating speed for a given voyage or route. By considering factors like weather, sea conditions, and ship design, operators can determine the optimal speed that balances voyage time and fuel consumption. The combined implementation of ship trim, draft optimization, and speed optimization strategies holds significant potential for the maritime industry to achieve substantial reductions in fuel consumption, operational costs, and environmental impact.

2.3 Artificial intelligence

Artificial intelligence (AI) is a rapidly growing field that has the potential to transform various industries, including shipping. This chapter provides an overview of AI, its history, and its current applications. The chapter also discusses the potential impact of AI on the shipping industry, specifically on sustainable business models.

AI is a field of computer science that focuses on the development of intelligent machines that can perform tasks that typically require human intelligence, such as learning, problem-solving, and decision-making. These machines can use various techniques, including machine learning, natural language processing, and robotics (Poole & Mackworth, 2017).

The idea of AI has been around since ancient times. However, it wasn't until the mid-20th century that AI became a formal field of study. In 1956, John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon organized the Dartmouth Conference, which is considered to be the birthplace of AI. Since then, AI has evolved rapidly, with new techniques and technologies being developed continuously (Russel & Norvig, 2021).

2.3.1 Applications of AI

This subchapter will provide an overview of how AI is currently being used in the shipping industry and its supporting activities.

In shipping, AI is being used to optimize vessel routing, reduce fuel consumption, and improve cargo handling. Maersk, one of the world's largest container shipping companies, has implemented AI algorithms to optimize vessel routing, resulting in significant fuel savings (Maersk, 2021). AI is also being used to improve cargo handling through automated container inspections and predictive maintenance (Guldbrandsson & Uden, 2019). AI algorithms can analyze data from various sensors and other sources to detect potential equipment failures before they occur. This can help shipping companies avoid costly downtime and repairs, as well as increase safety and reduce environmental risks (Gharehgozli et al., 2018).

AI technology is also applied to develop fully autonomous ships that can operate without crew members onboard. These ships are expected to improve safety, reduce costs, and enable more efficient use of space on board (IHS Markit, 2020).

In port operations, AI is being used to improve efficiency and reduce costs. AI algorithms are being used to optimize cargo handling, reduce waiting times, and improve terminal throughput (Ding et al., 2020). AI is also being used to improve safety through the use of predictive maintenance and condition monitoring of critical equipment (Gao et al., 2020). These algorithms can be used to track the movement of cargo in real-time and monitor its condition, such as temperature and humidity. This can help ports and shipping companies ensure the quality and safety of their products, as well as detect and prevent theft or damage. (Shen et al., 2019)

2.3.2 Impact on the shipping industry

AI has the potential to transform the shipping industry by increasing efficiency, reducing costs, and improving sustainability. By optimizing shipping routes and improving cargo handling processes, AI can reduce fuel consumption and emissions, leading to a more sustainable shipping industry. AI can also help shipping companies make better decisions, leading to increased profitability and competitiveness.

2.3.3 Random Forest Regressor

Regression is a statistical method that helps analyze and understand the connection between a variable that we want to predict (dependent variable) and other variables that may influence it (independent variables). By examining the values of these independent variables, regression helps estimate and forecast the value of the dependent variable.

Random forest regressor is a machine learning algorithm used for regression tasks. It is a type of ensemble learning method that combines multiple decision trees to create a more accurate and robust model. Each decision tree in the forest is built on a random subset of the features and a random subset of the training data. This helps to reduce overfitting (where a model becomes too tailored to the training data and perform poorly on new data), and improve the generalization of the model (Cutler et al, 2007).

Random forest regressor works by constructing a multitude of decision trees. Each decision tree independently makes a prediction for the target variable, and the final prediction is the average of the predictions of all the trees. This approach improves the accuracy of the prediction and makes the model more resistant to outliers and noise (Abdel-Rahman et al, 2013).

One of the main advantages of random forest regressor is its ability to handle high-dimensional datasets with many features. It can also handle missing values and maintain accuracy even with many irrelevant features. Additionally, random forest regressor can provide information on feature importance, which can be useful for feature selection (Section, 2020).

Random forest regressor has been used in a variety of applications, including finance, healthcare, and environmental modeling (Logunova, 2022). In the shipping industry, it has been used for tasks such as predicting fuel consumption, estimating ship arrival times, and optimizing shipping routes (Ran Yan et al, 2020).

2.3.3 Mixed-integer linear programming

Mixed-integer linear programming (MIP) is a mathematical optimization technique used to solve problems that involve discrete and continuous variables. In this approach, the objective function and constraints are formulated as linear functions of both continuous and integer decision variables. The objective is to find the optimal values of decision variables that satisfy the constraints and maximize or minimize the objective function (Modos, 2023).

MIP has a wide range of applications, including production planning, scheduling, resource allocation, and transportation. It is particularly useful in situations where decisions need to be made on discrete options, such as selecting the optimal number of machines to use in a factory or the optimal routes for a delivery fleet (C.F. Leite, 2022).

2.3.4 Artificial Neural Network

Artificial Neural Network (ANN) is a type of machine learning algorithm that is inspired by the biological structure of the human brain. It consists of interconnected nodes, known as artificial neurons, that work together to process information. ANNs are widely used for solving complex problems, particularly in the areas of image and speech recognition, natural language processing, and predictive analytics (IBM, 2020).

The basic building block of an ANN is the artificial neuron. It receives input from one or more sources and applies a mathematical function to that input to produce an output. The output of one neuron is typically connected to the input of another neuron, forming a network. ANNs can have multiple layers of neurons, with each layer performing a different type of calculation (Hardesty, 2017).

One of the key advantages of ANNs is their ability to learn from data. During the training process, the network is presented with a set of inputs and corresponding outputs. It adjusts the connection strengths between neurons to minimize the difference between the predicted output and the actual output. This process is repeated many times until the network produces accurate predictions on new data (Imran, 2020).

ANNs can be used for a wide range of applications, including image recognition, speech recognition, natural language processing, and predictive analytics (Kaushik, 2021). In the shipping industry, ANNs can be used for tasks such as predicting cargo volumes, optimizing shipping routes, and predicting maintenance needs (E. Bal et al, 2016).

2.4 Added value

Added value refers to the value that a business creates for its customers beyond the basic product or service that it provides (Baines et al, 2011). In sustainable business models, added value involves creating economic, social, and environmental value simultaneously, by balancing the needs of all stakeholders.

In the shipping industry, added value can be created through sustainable business practices. A study by Tello et al. (2021) explored the added value of sustainable business models in the shipping industry. The study found that sustainable business models can create added value for shipping companies by reducing costs, improving operational efficiency, and improving the company's reputation.

2.5 Sustainable business models

In recent years, sustainable business models have gained significant attention in academia and industry. This is due to the increasing concerns about climate change, resource depletion, and social inequality, among others. Sustainable business models are defined as “business models that create value for the company, its stakeholders, and society while reducing environmental and social impacts” (Boons & Lüdeke-Freund, 2013, p. 600). In the context of the shipping industry, sustainable business models are becoming increasingly important to meet the industry's environmental and social challenges while remaining competitive.

Sustainable business models are based on three key elements: economic, environmental, and social sustainability (Bocken et al., 2014). Economic sustainability refers to the ability of the business model to create long-term value for the company, its shareholders, and other stakeholders. Environmental sustainability focuses on reducing the negative impact of the business model on the environment, such as greenhouse gas emissions, waste generation, and resource consumption. Social sustainability aims to improve the well-being of society, including employees, customers, and local communities, by ensuring fair labor practices, human rights, and community engagement.

In their 2021 article "Sustainable business model innovation: A review", Geissdoerfer et al. discuss the importance of sustainable business models for achieving sustainable development goals. The authors argue that sustainable business models should be designed and implemented in a way that maximizes economic, environmental, and social benefits.
Furthermore, Geissdoerfer et al. explains that sustainable business model innovation can be seen as a process that involves the creation and implementation of new sustainable business models or the adaptation of existing models to better align with sustainability objectives. This process requires collaboration between stakeholders and the integration of sustainable principles into all aspects of business operations.

Sustainable business models can be categorized into several types, such as circular, sharing, and performance-based business models (Lüdeke-Freund & Gold, 2017). Circular business models aim to reduce waste and optimize resource use by designing products and services that can be reused, repaired, or recycled. Sharing business models promote the sharing of resources, such as transportation or accommodation, to reduce their underutilization and related environmental impacts. Performance-based business models focus on selling services rather than products, thus incentivizing resource use and efficiency optimization.

In the context of the Swedish shipping industry, sustainable business models can play a crucial role in reducing environmental impact and ensuring long-term viability. By adopting sustainable business models that leverage the benefits of artificial intelligence, shipping companies can for example use AI to optimize shipping routes and reduce fuel consumption, monitor, and control emissions, and enhance supply chain transparency and efficiency (Yaghoubi et al., 2019). AI can also facilitate the implementation of circular and sharing business models by enabling the tracking and traceability of resources and products, predicting maintenance needs, and optimizing resource use.

Geissdoerfer et al. also highlights the need for businesses to continuously evaluate and improve their sustainable business models. This can be achieved through the use of performance metrics that assess the economic, environmental, and social impacts of the model. By monitoring and improving the sustainability performance of their business models, shipping companies can ensure that they are contributing to the transition towards a more sustainable shipping industry.

Sustainable business models are essential for the Swedish shipping industry to meet its environmental and social challenges while remaining competitive. AI technology can support sustainable business models by improving resource efficiency, reducing environmental impacts, and enhancing transparency and traceability (Naz, 2022). Understanding the relationship between AI and sustainable business models is crucial for developing effective strategies and policies for the industry.

2.6 Data collection in shipping

The integration of artificial intelligence (AI) with Automatic Identification System (AIS) can mean a big change in the shipping industry. AIS requires vessels to transmit real-time data about their speed, location, and other details, and is mandated by law for larger ships to enhance maritime traffic safety (International Maritime Organization, 2021). AI algorithms and machine learning techniques can process and analyze vast amounts of AIS data, uncovering valuable insights and patterns. This allows for improved decision-making, situational awareness, and vessel traffic management. The potential benefits of integrating AIS and AI in the shipping industry include improving route planning, enhancing communication and coordination among ships and authorities, and transforming the way ships operate.

2.6.1 Automatic Identification System (AIS)

Ships send and receive data while out on sea to aid navigation and communication between ships and other maritime infrastructure. Automatic Identification System (AIS) transceivers transmit identifying information about the vessel such as name and vessel type, as well as other relevant data to minimize risks of collisions and reduce harm of incidents on board (Yang et al. 2019).

These transceivers are required by the International Maritime Organization on every vessel above 300 gross tonnage (International Maritime Organization, 2021). Though the main goal behind creating AIS was safety such as avoiding collisions, the collected data from ships is now also used for research as well as in a wide range of applications. As the AIS data available on board, the mariners have better understanding of safe routing, protected waters and the location of other ships. In ports, this data can be used for a wide variety of ways. The AIS data is essential in vessel traffic management as it tracks vessel positions in real time. This creates an opportunity to optimize berthing schedules and prevent congestion. AIS data is also utilized for real-time monitoring of cargo management and tracking, port resource planning, and emergency response, providing an up-to-date overview of port operations.

AIS was developed in the 1990s and uses VHF radio frequencies to broadcast information to receivers within its range. Signals are sent from the ship´s transceivers in different intervals ranging from seconds to minutes depending on which type of information and the speed of the vessel. This information is then decoded and reformatted to standardized messages. After filtering the redundant or faulty messages, the data is then integrated into databases where it can be used for specific applications. The data is then able to be used as a basis for analysis and mapping for a wide range of different information gathering and processing.

The Automatic Identification System also helps make mariners environmentally friendly as monitoring and reporting in real time can make companies comply more with regulations. Tracking vessel efficiency, ballast water exchange and emissions are all possible ways to mitigate environmental impacts of sea transport on a local as well as global level. AIS data is also of use in studying different impacts of maritime trade. For example, AIS data has been used to evaluate ocean noise pollution (Williams et al., 2019) with the intention of studying long term effects of shipping on underwater fauna.

2.6.2 DBSCAN

DBSCAN (Density-Based Spatial Clustering of Applications with Noise) is a widely used clustering algorithm in the field of artificial intelligence (AI) integration in shipping. It is particularly useful for analyzing large datasets like Automatic Identification System (AIS) data commonly employed in the maritime industry. DBSCAN clusters data points based on their density, grouping together points that are close to each other and have a sufficient number of neighboring points. Unlike other algorithms, DBSCAN does not rely on predefined shapes or distances. It can effectively detect irregularly shaped clusters and handle noise and outliers (Khan, 2014). In the context of AI integration in shipping, DBSCAN can be applied to uncover valuable insights from AIS data, including identifying vessel traffic patterns, detecting anomalies, and optimizing routes. By utilizing DBSCAN, AI algorithms can leverage hidden patterns in AIS data to provide decision-making support for various maritime operations (Zhang et al, 2023).

2.6.3 AIS and AI

AI integration with Automatic Identification System (AIS) is a rapidly emerging area of research and innovation in the maritime industry. The sheer volume and complexity of AIS data presents challenges in extracting meaningful insights. This is where AI comes into play.
The integration of AI with AIS involves the use of advanced algorithms and machine learning techniques to process, analyze, and extract valuable information from AIS data. AI can handle the vast amount of data generated by AIS, including vessel positions, speeds, headings, and other contextual information, and uncover patterns, trends, and anomalies that may not be easily discernible by human operators.

One key area where AI integration with AIS is gaining traction is in vessel traffic management. AI algorithms can analyze AIS data in real-time to predict vessel movements, optimize routes, and improve traffic flow (Mouzakitis et al., 2022). Additionally, AI can enable predictive maintenance of vessels by analyzing AIS data to detect potential equipment failures or maintenance needs, leading to improved operational reliability and reduced downtime (Jaramillo Jimenez et al., 2020).

Another important application of AI integration with AIS is in maritime safety and security. AI can analyze all the AIS data to detect abnormal vessel behaviors, such as deviations from intended routes or suspicious activities, which can aid in identifying potential security threats. Additionally, AI can assist in identifying vessels that may be involved in illegal activities, such as smuggling or piracy, by collecting the vessel´s unique identification number (MMSI-Maritime Mobile Service Identity) and other relevant information.

Furthermore, AI integration with AIS has the potential to enhance environmental monitoring and conservation efforts. By combining AIS data with other environmental data, such as satellite imagery and oceanographic data, AI can develop predictive models for assessing the environmental impact of vessel traffic, identifying potential risks to marine ecosystems, and supporting sustainable practices in the maritime industry.

2.6.4 Distributed Ledger Technology

Distributed Ledger Technology (DLT) is a term used to describe a database system in which data is stored across a network of decentralized nodes, rather than being held in a centralized location. This allows for increased security, transparency, and efficiency in data management. DLT is the foundation for many digital currencies, such as Bitcoin and Ethereum, but it has broader applications beyond just cryptocurrency (The World Bank, 2018).

In recent years, the shipping industry has shown increasing interest in DLT due to its potential to improve operational efficiency, increase transparency, and reduce costs. By using DLT, shipping companies can reduce the time and resources required for documentation and administration, which can ultimately result in faster and more cost-effective shipping practices (CSIS, 2021).

One of the key benefits of DLT is its ability to create a tamper-proof record of transactions (CSIS, 2021). This is particularly important in the shipping industry, where large amounts of data are generated across multiple stakeholders and can be subject to fraud or errors. By using DLT, shipping companies can create a shared, immutable ledger of all transactions, which can be accessed and verified by all parties in the network. This can help to reduce disputes and fraud, as well as increase transparency and accountability.

Another potential application of DLT in the shipping industry is the creation of smart contracts. Smart contracts are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. They allow for automation of routine tasks and can significantly reduce the time and resources required for administrative tasks, such as bill of lading creation and verification. This can ultimately lead to faster and more cost-effective shipping practices (CSIS, 2021).

Overall, the use of DLT in the shipping industry has the potential to significantly improve operational efficiency, reduce costs, and increase transparency and accountability. As more companies in the industry adopt this technology, it is likely that we will see continued innovation and development in this area.

3. METHODS

In this chapter, methods that were used to answer the research questions will be brought up and explained.

3.1 Case Study

This study employed a case study research design to investigate the subject of the added value of AI technology on sustainable business models in the Swedish shipping industry. A case study approach was chosen because it allows for an in-depth examination of specific companies that meet the specifications required for the study (Yin, 2018). Furthermore, it allows for more tailored interviews with company officials that are knowledgeable in the subject. Another benefit of a case study method is the opportunity for more personal and in-depth dialogues as opposed to doing a survey (Baxter & Jack, 2008). The case study was employed to collect the primary data for this study but were upon further review used as secondary data.

Before the case study was conducted, a market analysis was done to find out about the current state of the Swedish shipping industry in terms of AI. This was done by attending an industry trade fair called "SjöLogg". This trade fair is for shipping and logistics companies, which made it a suitable place to speak to companies about AI as well as finding potential candidates for the case study. Close to all attending companies were asked about their thoughts about AI and if their company is currently implementing it or plan to. The companies were also asked if they could appoint an employee in the company that could potentially answer more in-depth questions. These employees were contacted through email and asked if they would like to participate in a case study through an interview. A business developer from the Swedish maritime administration (Sjöfartsverket) with over 30 years of experience in the industry accepted and were later interviewed. Due to no other company contacted having implemented AI or had any expertise on the subject, this was the only interview held. A set of 12 preliminary questions were prepared before the interview and served as a base of discussion with the interviewee (See Appendix A). The questions were tailored to inquire about the company's implementation of AI. Due to the Swedish Maritime Administration not having implemented the technology to the degree that was expected, the interview later diverged from the questions and the interviewee spoke freely about the topic. The structure of the interview became that of a discussion, where the interviewee brought up relevant topics that inspired follow-up questions. In this way the interview yielded relevant information without being confined to the predetermined questions. The data obtained through the interviews was supposed to be used as the primary data in the study. Due to low participation from the companies contacted, it was decided that the information obtained from the interview were to be used as secondary data to back up the data collected from the literature review.

Worth mentioning is that ethical considerations were taken into account throughout the research process. All participants provided informed consent, and their anonymity was protected. The study was also reviewed and approved by Chalmers supervisors and examiners.

3.2 Literature review

In addition to the case study, a literature review was employed to collect the secondary data used in the study. Due to low participation and a lack of information provided by the companies contacted for the case study, the method of research was reconsidered, and it was decided that the literature was to be used as the primary source of data for the study.

The literature review is a crucial aspect of the research process and plays an integral role in providing a theoretical foundation for the study. This section will outline the steps that were taken to conduct a literature review to collect data for the study.

Based on the research questions, the mixed method approach was the most suitable for the study. The quantitative component enabled us to quantify the economic and environmental benefits of AI integration using measurable indicators to provide concrete insights into the impact of AI on sustainability. On the other hand, the qualitative component allowed us to delve deeper into the prospects and perspectives of AI integration in the Swedish shipping industry. This approached helped us look at the objective data from the studies and combining it with subjective opinions and expectations, leading to a more nuanced discussion.

Quantitative indicators, such as cost reductions, emission data and efficiency gain were all analyzed to assess the economic and environmental value added by AI. This guided the literature search towards the most definite and objective data than could support the arguments proposed.

A systematic literature search was used as the primary method of the literature search. The systematic literature search was conducted by treating the search process in a structured and preplanned manner. It demands careful consideration of search terms, selection of databases, and choice of search methods, and requires reflection on the search results obtained during the process (Tranfield, Denyer, & Smart, 2003).

Firstly, relevant keywords and search terms related to our research topic were identified. These keywords included but were not limited to: "artificial intelligence", "sustainable business models", and "shipping industry". These keywords were used to conduct a systematic search of various academic databases such as Web of Science, Scopus, and Google Scholar. From this initial search 408 articles were identified.

Secondly, we applied inclusion and exclusion criteria to filter out articles that were not relevant to our study. The inclusion criteria comprised articles that were published in the past ten years, written in English, and discussed relevant topics such as AI, sustainable business models, the shipping industry, added value, and so on. The exclusion criteria comprised articles that were not peer-reviewed, not published in academic journals, or not related to our research topic. This resulted in 127 articles. Some exceptions were made to these criteria, for example when the source wasn't used to directly answer the research questions. Another exception from these criteria were books rented from the public library, these sources were mainly used in the theory to create a deeper understanding of a specific topic.

Thirdly, the quality of the articles that were selected for inclusion in the literature review was assessed. A critical appraisal tool was used to evaluate the validity, reliability, and relevance of the articles. The critical appraisal tool enabled the identification of any biases or limitations in the articles and ensured that the articles met the required standards for the study (Aromataris et al, 2015). The final number of scientific articles for analysis was 28.

In addition to the systematic literature search, the snowball sampling method was conducted to gather additional relevant information and studies on the research topic. Snowball sampling is a non-probability technique in which existing articles are used to find additional articles through the references (Babbie, 2016). This method was used to gather sources from the articles that already had passed through the assessment for inclusion.

Lastly, the data from the selected articles were synthesized and organized into themes and categories. We used a thematic analysis approach to identify patterns and trends in the literature and to draw conclusions about the research topic. The literature collected was familiarized through reading and re-reading the selected articles. Relevant text fragments related to the research questions were highlighted and labeled. These were then organized into themes, which represented a commonality or coherence in the literature.

The themes were reviewed and revised as necessary to ensure accuracy in capturing the essence of the data. The themes were collated to generate an overarching narrative about the subject. This involved synthesizing the themes and drawing connections between them to provide a comprehensive understanding of the research topic.

Overall, the literature review process allowed for the gathering of relevant data and insights on the use of AI in the shipping industry, which served as the basis for the results and conclusions.

4. RESULTS

In this chapter the results of the study will be presented regarding the research questions. Sustainable business models consist of three main elements; economic, environmental, and social sustainability (Bocken et al., 2014). How AI adds value to business models by creating better economic and environmental sustainability will be presented, as well as the prospects for the Swedish shipping industry to implement this technology.

4.1 How does AI add value in terms of economic and environmental sustainability?

The integration of AI in shipping has potential to add value in sustainable business models in multiple ways. Preliminary research shows that AI integration can enable sustainable business models and can add value to these business models through making aspects of shipping more efficient and safer. Social pressures regarding climate concerns, affordability and efficiency are all factors that lead to a greater interest in innovative solutions in supply chains, and AI is showing promise in aiding in accomplishing these goals. The research depicts AI as an effective tool for helping mariners, ports, and suppliers with many tasks and helps them make more educated and sustainable choices.

Some of the main applications of AI will now be presented and explained in terms of how they add value and contribute to sustainability.

4.1.1 Energy efficiency and emissions reduction

One of the biggest environmental impacts of shipping is the release of greenhouse gases (GHG) into the atmosphere. By utilizing the data available from ships, the AI can help make decisions and predictions based on a wealth of information that couldn´t be processed by individuals. More efficient routes lead to lower costs and lower environmental impact, both of them being indicators of a sustainable business model.

In a study by Ran Yan et al. (2020), they proposed a two-stage AI-model to predict and reduce fuel consumption for a dry bulk ship. They developed a random forest (RF) regressor for ship fuel consumption prediction and a mixed-integer linear programming (MIP) model to optimize ship sailing speed. The model incorporated various factors, such as speed, draft, weather, and wave conditions, to predict fuel consumption accurately. The study proved that the proposed model could accurately predict the fuel consumption of the dry bulk ship. Additionally, the model identified potential areas for fuel consumption reduction, such as adjusting the vessel's speed and optimizing the main engine's performance. The results of their experiments show that with using the AI-technology to predict fuel consumption and optimizing sailing speed, 2–7% of fuel can be saved compared with a real situation of twelve days of continuous voyage (Yan et al, 2020). This is empirical evidence showing that the use of AI in this case added value through lowering bunker consumption which leads to lower emissions and less money being spent on fuel. These are of course great indicators of improved economic and environmental sustainability.

In another study by Brouer et al. (2017) a speed optimization model by Reinhardt et al. (2016) was presented. This AI-supported model was simple and effective and could optimize the speed of an existing liner shipping network while taking transit times and service level into account. This model showed to be able to save 2% of bunker consumption while maintaining consistent transit times. If an extension of up to 48 hours in transit times is possible, a saving of around 6–7% is achievable (Reinhardt et al., 2016).

This use of AI could lead to remarkable savings in bunker consumption without significantly altering the service level, promoting both environmental and economic sustainability through lowering bunker consumption while not affecting the liner service's commercial activities.
A study by E. Bal et al. (2016) shows an example of an artificial neural network (ANN) lowering fuel costs and emissions models in a controlled voyage compared to the widely used multiple regression analysis (MR). The study was based on a data set collected from 233 noon reports (daily reports of the fuel consumption of the vessel) where 70% of the data was selected for training the neural network and the remaining 30% was used as validation for the data. The fuel prediction model based on the ANN used trim, revolutions per minute (RPM), ship speed, draft, cargo quantity as well as wind and sea conditions to extract fuel consumption data. The results were a cost reduction of 10,470 dollars and 165t of CO_2 emissions on an 800 nautical mile voyage at compared to a multi regression analysis. This indicates that neural networks have potential to further minimize the emissions and lower cost compared to the more common approaches.

4.1.2 Predictive technology and equipment optimization

AI integrated with onboard ship instruments and port systems provides a cost-effective approach to maintenance by predicting and indicating the need for maintenance in onboard equipment. The cost of replacing individual parts of machinery can be high, both directly and indirectly. Predictive maintenance minimizes logistical struggles caused by sudden breakdowns, making shipping safer and reducing downtime. AI enables companies to proactively schedule maintenance with fewer in-person inspections, significantly lowering costs (Surucu et al, 2023). In addition, predictive maintenance reduces the risk of ecological disasters and associated aftermath.

A study by Haiwen et al. (2023) looked at creating a model for predicting the optimum trim of any vessel and voyage using machine learning algorithms. Optimizing trim is a useful way to make ships more efficient and sustainable through lowering the hull water resistance based on water and weather conditions. Trim adjustment technology is available and being used on most ships, and optimizing trim is a comparatively cheap way of reducing emissions in accordance with current emission reduction requirements. Currently, predictive models are built based on specific vessel characteristics which creates a need for optimization models tailored to different ship designs. The authors argue that better predictive and more universal models economically benefit the shipping market through lower development costs, lower operational cost, and environmental footprint. They also point to the fact that the impact of more efficient predictive models is tied to the level of adoption in the current maritime landscape. Therefore, models that are easily applied to a wide variety of vessels is important considering the current challenges with GHG emissions and the need of accessible and effective, applicable solutions. The study evaluated four different predictive models based on the data from six 4250-TEU container ships and concluded that the Random Forest Model is the best option for wide application (Haiwen et al., 2023).

4.1.3 Supply chain optimization and waste reduction

Routing and maintenance are important aspects of the optimization of supply chains. However, storage efficiency and better consolidation also adds value both economically and environmentally. AI can help inform the crew and ports of storage levels in real time which greatly help the port and shippers to consolidate shipments more efficiently. This lowers the risk of over or under stocking which minimizes waste and excess production when integrated into the supply chain. Storage conditions on board can be evaluated in real time to enable the mariners to optimize conditions which lead to less waste and lower risk of damaged goods.

In a study by Vujicic et al. (2020), they investigated the use of Distributed Ledger Technology (DLT) as a tool for environmental sustainability. The paper looks at the possible applications of using DLT to aid the control of wastewater discharge from commercial ships. Discharging wastewater in areas where it is prohibited to do so causes significant environmental harm, including damage to marine ecosystems, depletion of oxygen levels in the water, and contamination of seafood, among other (U.S. EPA, 2022). Therefore, increasing the control over wastewater discharge would reduce these detriments and thus improve environmental sustainability in the shipping industry.

The model that the authors present facilitates information sharing in the shipping industry between multiple parties such as shipping companies, port authorities, harbor masters, coast guards, and national legislators. The information is stored in a public cloud architecture, allowing access and validation from different parties while complying with privacy regulations. Advanced Optical Charter Recognition (OCR) technology is used to collect and upload real-time data related to ship operation discharge. This information is traceable through the platform via blockchain technology. In this process, data is validated by all parties involved to reach a consensus, and then the records are stored securely in the centralized ledger of the blockchain system, which makes them unchangeable. As a result, intermediaries and internal departments that previously dealt with paper records through manual operations are no longer necessary, and the records are now tamper-proof. (Vujicic et al, 2020).

The authors found that the utilization of this model can address various concerns in the shipping industry such as reducing administrative expenses, promoting eco-friendly solutions, safeguarding against piracy and cybercrime, and guaranteeing fair practices for all stakeholders involved. With the implementation of DLT and critical safety measures, marine pollution can be averted. The technology could be used to facilitate informed decision-making, which is in the best interest of all parties involved.

In a scoping review and future research agenda by Pandl et al. (2020) they state that there are promising prospects of convergence between artificial intelligence and distributed ledger technology. By leveraging DLT with AI there is a potential for even greater benefits of the technology. Vujicic et al. explains that the biggest weakness with the presented model is the disc space. By integrating AI-technology within the model it can monitor data in real-time and provide analytics of the obtained data, and then extract the data that is useful. This eliminates the most prominent issue with this model and increases the value it adds to improve sustainability. Another issue that the authors bring up is the data security. AI can play a vital role in enhancing the security of DLT systems by detecting and preventing cyber-attacks (Frackiewicz, 2023). The use of AI-powered cybersecurity tools can help identify potential threats and vulnerabilities in the system, allowing for immediate action to be taken to prevent any unauthorized access or data breaches. AI algorithms can also be used to continuously monitor the blockchain network for any suspicious activities, flagging any potential threats in real-time. Additionally, AI can be used to develop predictive models that can anticipate potential security risks and recommend proactive measures to mitigate them. By integrating AI with DLT, the blockchain network can become more resilient, secure, and trustworthy, ensuring the integrity and reliability of the data stored on the blockchain.

4.1.4 Route optimization and risk management

AIS data is emerging as one of the best ways to gather big data sets that can be used for many different applications. AIS is mandated by the IMO and thus widely adopted by the shipping industry to increase safety and the lower risk of collisions. AIS systems onboard collect a wealth of data pertaining to a ships position, speed, course, ETA (estimated time of arrival) as well as other safety related data. This data can be used in conjunction with AI to improve predictive capabilities of these factors as well as broaden the scope of the uses of AIS (Tritsarolis et al, 2022).

The findings of the studies conducted by Wen et al. (2020) and Kontopoulos et al. (2021) contribute valuable insights to the field of route optimization in shipping. Wen et al. applied the DBSCAN algorithm to accurately extract turning sections of a ship's trajectory, leading to the development of an automatic route design algorithm. This approach holds promise for improving route efficiency and reducing fuel consumption. Kontopoulos et al. utilized historical AIS data and introduced modifications to the DBSCAN algorithm to identify coherent shipping lanes. Their analysis of future vessel paths revealed a significant alignment (over 90%) with the extracted shipping lanes. These findings highlight the potential of AI-based methods in identifying optimal shipping routes. Furthermore, both studies recommend further research to consider dynamic constraints in real-time, such as water velocity, and to incorporate 3D information for more precise and comprehensive route planning. These suggestions pave the way for future investigations in enhancing the accuracy and effectiveness of AI-integrated route optimization in the shipping industry.

A study by Yang et al. (2019) shows research pertaining to AIS and its extended applications are increasing. The analysis reveals a notable surge in the number of studies from 2010 onwards, indicating a rapid growth in the field. Additionally, the topics covered in these studies have become increasingly diverse over time. Furthermore, since 2014, the number of advanced application papers has nearly reached parity with basic application papers. This demonstrates the evolving nature of AIS research, with a shift towards more complex and advanced applications.

One of these applications being researched is the utilization of AIS data to enable the possibility of autonomous ships using deep reinforcement learning. Shen et al. (2019) describe that reports indicate human error of mariners is a contributing factor in approximately 89-96% of maritime collisions. Furthermore, it has been identified that 56% of these collisions occur due to violations of the International Regulations for Preventing Collisions at Sea (COLREGs) established by the International Maritime Organization (IMO). As a result, there is a presumption that a substantial reduction in collisions can be achieved by enhancing ship automation, specifically for collision avoidance in line with safety guidelines.

4.2 What are the prospects for adding value through AI integration in the Swedish shipping industry?

AI integration in the global shipping industry has the potential of adding value to businesses through the different avenues presented in the above chapter. The studies show no indication that these value adding practices would not be applicable to the Swedish shipping industry, which indicates the benefits of AI integration would apply in Sweden as well.

Currently, there is a lack of quantitative data showing the impact of AI in the Swedish shipping industry, which makes evaluating current practices and benefits of AI in this sector difficult.

Because of this, an interview with an AI-interested business developer at the Swedish Maritime Administration was conducted. The purpose of the interview was to get an understanding of AI implementation in the Swedish shipping industry today, as well as to give insight into some plans for future AI projects in Sweden. According to the interviewee, a surge of AI-implementation in Sweden could be close. As more companies start to see its commercial benefits, adoption necessarily follows. This statement is agreeable due to Sweden's advanced digital infrastructure, strong focus on innovation, and high level of technological expertise. Sweden ranks 4th of 27 EU Member States in the 2022 edition of the Digital Economy and Society Index (DESI) (EC, 2022). The results from the interview and the level of technological development in Sweden point to the theory that the Swedish shipping industry is well-positioned to take advantage of AI technologies.

The use of AI has been looked at by the Swedish maritime sector, and some projects have been started to evaluate the benefits regarding sustainability from AI integration.
Both the Swedish coast guard and the Swedish Maritime Administration has had AI projects in development. These consists of predictive maintenance of buoys as well as using AI to recognize distress calls. Even though these projects looked promising and was close to the stage of implementation, both ceased. The reason the first project was aborted was because of resistance from clients due to the developers not following the conventional code of conduct. The other example was a Swedish municipality buying an AI-based system and then being forced to switch suppliers for the service. This caused a lot of questions regarding who owns the data, which the lawyers didn't have an understanding about. Because of this the system was never implemented (A business developer at the Swedish Maritime Administration, personal communication, March 30, 2023).

According to the interviewee, the implementation of AI technologies such as predictive maintenance, autonomous vessels, and smart logistics systems can help optimize the shipping industry's operations and make it more competitive and sustainable (A business developer at the Swedish Maritime Administration, personal communication, March 30, 2023).

The business developer voices his concerns regarding the implementation of AI in the Swedish shipping industry. The challenges that the industry is facing for a widespread implementation to be possible is mostly regarding law. Who is liable if something were to happen and who owns the data are both big concerns for a lot of companies. The need for reliable connectivity and adequate infrastructure may limit the adoption of AI by smaller companies. Then there is a lack of understanding of AI which can cause fear and doubt in some clients, which creates a resistance to implementation. Human factors and workforce impacts were also identified as key considerations in the adoption of AI in shipping. While AI can automate routine tasks and improve efficiency, it can also lead to job displacement and changes in the skills required by the workforce. Therefore, shipping companies need to consider the impact of AI on their workforce and develop strategies to upskill and reskill their employees to ensure a smooth transition to AI-enabled operations. This seems to be the consensus of a lot of industry experts regarding the matter, according to the interviewee.

This indicates that the successful integration of AI technologies into the Swedish shipping industry requires careful planning and consideration of numerous factors, such as data privacy, regulatory compliance, and workforce training. It also shows how important studies and empirical data on the benefits of AI-implementation in the shipping industry is. Lawmakers, company officials, and clients needs to get a better understanding of AI and the value it adds before the surge of implementation can begin.

In conclusion, the results suggest that AI integration has promising prospects for adding value in the Swedish shipping industry, but its implementation should be carefully planned and executed to maximize the benefits and minimize the risks.

5. DISCUSSION

The aim of the study is to create an understanding of how AI can be used to make shipping more sustainable through creating economical value and lowering its environmental impact. To examine the role of AI in shipping, we conducted a literature review examining relevant studies and reports on the topic. In addition to this, the prospects of implementing AI to add value in the Swedish shipping industry was explored by conducting an interview with an industry expert and by reviewing literature on the topic.

5.1 Our findings

The main findings of our study shows that AI can indeed add value to sustainable business models by improving economic and environmental sustainability. In the research paper by Yan et al (2020), they showed that by using AI-technology to optimize fuel consumption, 2–7% of fuel can be saved compared to a voyage not using the technology. In another study by Brouer et al. (2017), a method of using AI-technology to optimize the speed of a vessel was presented, this use of AI proved to save 2% of bunker consumption while maintaining consistent transit times. If transit times could be extended to up to 48 hours, a saving of around 6–7% was achievable. In a study by E. Bal et al. (2016), the authors showed that by using an Artificial Neural Network for fuel prediction savings of 10,470 dollars and 165t of CO_2 emissions could be made, compared to not using the technology. These studies showed the value that the AI-technology added through empirical data on how it lowered costs and emissions. This is important because most literature on AI in the shipping industry does not provide clear and tangible evidence of its benefits, thus making their findings less reliable. In these cases, the results indicate a clear connection between the use of AI and improved economic and environmental sustainability through emitting less pollution and by saving money on bunker. Worth mentioning is although these research papers passed our inclusion criteria and helped greatly in answering the research question, AI and its capabilities are evolving at a rapid pace and every new iteration is vastly more powerful than the last. This may make some of the available historical data unrepresentative of the current potential of added value from the AI technologies available today. It is also exceedingly difficult to infer the potential prognosis for the future, since the capabilities most likely will continue to develop and grow, along with security risks and challenges of assessing decisions made by the AI. With this said, we believe that the value that AI can add to shipping practices will only increase with time. As long as the industry can overcome the challenges of implementation.

In the study by Vujicic et al. (2020), the authors researched the use of DLT to facilitate information sharing between all relevant stakeholders. The use of their proposed model showed to be able to reduce administrative expenses, avert maritime pollution, promote eco-friendly solutions, safeguarding against piracy and cybercrime, and guaranteeing fair practices for all stakeholders involved. It could also support informed decision making. Through overlapping themes in the literature between DLT and AI, we could draw the conclusion that AI has the potential to support this DLT model by increasing its reliability through data analytics and its security by detecting and preventing cyber-attacks. Although AI shows great promise of being able to aid DLT, it might be limited. Pandl et al. (2020) mentions that at the time the article was written, AI-based systems didn't have the capabilities required to govern a DLT system securely and robustly. This implies that current AI technology might not be advanced enough to aid DLT to the extent that we initially thought. But this is speculation since the developments of AI has had surge in recent years. More research is needed on current AI-based systems and their convergence with DLT to give definitive statement about how they can interact.

There were of course other findings related to the first research question, but these were the main ones that showed empirically that AI can improve economic and environmental sustainability in shipping practices. Other findings shared the same consensus that AI can be used to add value by lowering costs and environmental impact through optimizing shipping routes, fuel consumption, cargo consolidation, decision making and by predicting maintenance and increasing safety for example.

5.2 Case study findings

Moving on to the main findings on the second research question. It was found that the Swedish shipping industry shows good potential of implementing AI to add value to its sustainable business models. Advanced digital infrastructure, strong focus on innovation and sustainability, and high level of technological expertise gives Swedish shipping companies a good foundation to start implementing the technology. The significant benefits that AI-integration can create would most likely be possible to achieve in Sweden as well. AI has already been experimented with in certain sectors of the coast guard and for predictive maintenance of buoys. However, the timeline for AI integration in the Swedish shipping industry is unclear. Despite this, the increasing level of AI integration and its tangible benefits are clear, and a global trend of moving towards AI integration can be observed. The rate of implementation of AI is still slow, this is partly because the shipping industry tends to be slow in applying new ways of conducting business, but also due to some challenges halting a widespread implementation. These include data security and ownership, regulatory compliance, the industry's willingness to adopt, as well as a general lack of knowledge about artificial intelligence. We will now discuss these challenges and our thoughts on how they can be alleviated for the industry to be able to reap the rewards of AI.

5.3 The challenges of AI integration in shipping

AI relies heavily on data, and concerns about data security and ownership can hinder its implementation. Shipping companies may be reluctant to share sensitive data with AI systems due to privacy and security risks. Addressing these concerns requires robust data protection measures, including encryption, access controls, and secure data sharing protocols. Clear agreements on data ownership and usage rights between stakeholders might also help alleviate concerns.

The shipping industry is subject to various regulations and standards. Integrating AI technologies should align with existing regulatory frameworks, ensuring compliance with data protection, safety, and environmental regulations. Close collaboration between industry stakeholders, policymakers, and regulatory bodies is crucial to establish guidelines and standards for AI implementation that meet regulatory requirements.

The shipping industry may exhibit varying levels of willingness to adopt AI due to factors such as cost, perceived risks, and organizational culture. Overcoming this challenge requires demonstrating the benefits and value of AI through pilot projects, case studies, and success stories. Collaborative initiatives, industry partnerships, and knowledge-sharing platforms can help build confidence and encourage industry-wide adoption.

Many stakeholders in the shipping industry may have limited knowledge and understanding of AI and its potential applications. Addressing this knowledge gap necessitates educational and awareness-building initiatives. Training programs, workshops, and industry conferences focused on AI can help enhance awareness and understanding among shipping professionals.

Partnerships with research institutions and technology providers can facilitate knowledge transfer and exchange of best practices.

Another challenge is the lack of standardization in AI systems used in shipping. This can create interoperability issues and hinder collaboration and innovation. Shipping companies need to work together to develop common standards and protocols for AI systems to ensure that they can be integrated seamlessly and effectively. Additionally, AI systems can have unintended consequences that are difficult to predict. Shipping companies need to carefully consider the potential unintended consequences of AI integration and take steps to mitigate these risks.

Furthermore, AI systems may raise ethical concerns related to bias, discrimination, and accountability. Shipping companies need to ensure that their AI systems are designed and deployed in an ethical and transparent manner, and that they are held accountable for the decisions made by these systems.

To overcome these challenges, it is essential to foster a collaborative ecosystem that involves shipping companies, technology providers, regulators, and researchers. Engaging in open dialogue, sharing experiences, and establishing industry-wide guidelines and standards can promote trust, address concerns, and pave the way for a widespread and successful implementation of AI in the shipping industry.

Based on these findings, it can be concluded that there are indeed prospects for adding value through AI integration in the Swedish shipping industry. However, it is important to acknowledge the limitations of the study that may have influenced the results.

5.4 Limitations of the study

Firstly, the low participation of companies in the case study may have skewed the results to a certain degree. As only the Swedish Maritime Administration were included in the study, the findings may not be generalizable to the entire Swedish shipping industry. Therefore, caution should be exercised when interpreting the results and applying them to other contexts.

Additionally, the main data that was used to answer the second research question was based on only one interview with an industry expert. In addition to this, the literature regarding the Swedish shipping industry and AI was insufficient. Therefore, we didn’t have enough data to go as deep as we would’ve wanted. This resulted in an inadequate result in our opinion. We wanted to have multiple interviews with industry experts and company officials so that we could get different perspectives, and then draw our conclusion based on them. Although the expert's insights were valuable and provided useful information, the results may not reflect the opinions and experiences of a wider range of industry professionals. Thus, the findings should be considered in light of this limitation. In hindsight, we should have contacted companies from the industry at an earlier stage of the of the project. By doing this, we could have found out about the lack of implementation and understanding of AI at Swedish shipping companies before committing to the industry segment. This could also have made us reconsider the methodology of the study, as the case study was meant to be our main source of data for the results.

Despite these limitations, the results of this study suggest that there are opportunities for adding value through AI integration in the Swedish shipping industry. The findings can serve as a starting point for further research and can be useful for companies and policymakers who are interested in exploring the potential benefits of AI in this industry.

There were also some limitations regarding the first research questions. Something that surprised us when evaluating AI-integration in shipping was the lack of empirical data of its benefits such as lower costs and environmental impact.
We had hoped to find more studies showing definitive evidence of this as it would strengthen the notion that AI adds value to sustainable business models. We would've also wanted to explore the added value of AI on sustainable business models as a whole, including the social sustainability aspect. While AI integration in shipping can improve economic and environmental sustainability, it is harder to argue that it can contribute to a more holistic sustainability, which includes social sustainability. AI integration can lead to displacement of workers, which would have negative social consequences. Additionally, AI systems will fulfill the purpose for which they are created, which can lead to them being ignorant of social factors. Therefore, it is important to consider the potential social implications of AI integration in shipping and take measures to mitigate negative consequences. We felt that social sustainability was too hard to analyze as it is much more subjective than the economic and environmental aspects. This is an area where further research is needed. Another limitation with our research paper is that no figures were used. There was a lack of relevant free-to-use figures, and our request to use copyrighted figures was unanswered. With figures in our study, we could've made parts of the research easier to comprehend.

Regardless of these limitations, by demonstrating how AI can improve economic and environmental sustainability in the shipping industry, we hope our study can contribute to the development and adoption of more sustainable practices. This is crucial in addressing the environmental challenges faced by the industry and promoting its long-term viability. Our findings provide practical insights into how AI can be implemented in the shipping industry to achieve economic and environmental benefits. This information may help industry professionals, policymakers, and researchers in making informed decisions regarding the integration of AI technologies. Our study also fills a research gap by specifically examining the role of AI in adding value to sustainable business models by improving economic and environmental sustainability in the shipping industry. By focusing on this intersection, we contribute to a more comprehensive understanding of the potential benefits and challenges associated with AI adoption in the industry. Furthermore, we wish the findings and conclusions of our study can inspire and stimulate further research on the topic. Researchers can build upon our work to delve deeper into specific aspects, investigate different AI applications, or explore the potential synergies between AI and other sustainability strategies in the shipping industry

6. CONCLUSION

In this study, the primary aim was to assess how AI adds value in terms of environmental and economic sustainability in the global shipping industry and to explore the prospects for AI integration in the Swedish shipping industry. Through a review of relevant literature and interview with an industry expert, we were able to gather valuable insights and draw several conclusions.

Firstly, the results indicate that AI integration in the shipping industry has the potential to add significant value, particularly in terms of efficiency, sustainability, safety, and customer experience. By optimizing routes, reducing fuel consumption, and predicting maintenance, among others, shipping companies can save costs and decrease their environmental footprint. This concludes that in the studies reviewed, AI-implementation improves sustainable business models in shipping practices. AI can also position shipping companies as environmentally responsible, attracting customers who prioritize sustainability. Additionally, real-time tracking and proactive communication can enhance the customer experience and build brand loyalty. These conclusions were made by analyzing research papers and empirical evidence from existing literature on the topic.

Most of the published research on the use of AI and its connection to improved environmental and economic sustainability in the shipping industry points to it’s potential to be implemented and improve several aspects of shipping practices. However, actual data that supports this is scarce. This makes drawing conclusions hard as it is mostly based on speculation. This meaning that the consensus of the research made on the subject, is that AI technology can reduce environmental impact as well as operational costs when applied in shipping practices. This conclusion can be drawn based on theory and logic in addition to the available data, but more empirical data is required to make more definitive statements on the subject.

Furthermore, the implementation of AI in shipping faces multiple challenges. These challenges include but are not limited to; data security and ownership, regulatory compliance, the industry's willingness to adopt AI, and a general lack of knowledge about artificial intelligence. Reliable connectivity and adequate infrastructure are critical, which may limit the adoption of AI by smaller companies. Human factors and workforce impacts were also identified as key considerations in the adoption of AI in shipping. To overcome these challenges, it is crucial to cultivate a collaborative environment that encompasses every major stakeholder. Encouraging open communication, exchanging knowledge and insights, and establishing unified industry guidelines and standards can foster trust, mitigate apprehensions, and facilitate the extensive and effective integration of AI in the shipping sector.

Regarding the prospects for AI integration in the Swedish shipping industry, the study found that the prospects are promising. The Swedish shipping industry is well-positioned to take advantage of AI technologies due to its advanced digital infrastructure, strong focus on innovation, and high level of technological expertise. However, the implementation of AI requires careful planning and consideration of numerous factors, such as data privacy, regulatory compliance, and workforce training. This conclusion was drawn based on the interview in addition to previous research.

In conclusion, the results suggest that AI integration has a great potential to add value and promote sustainability in both the global and the Swedish shipping industry, but careful planning and execution are necessary to maximize benefits and minimize risks.

6.1 Recommendations for further research

Based on the findings of this study, several avenues for further research can be suggested. These recommendations aim to deepen the understanding of the role of AI in enhancing sustainability and identify opportunities for future advancements in the field. The following areas are particularly worth exploring:

Social Sustainability in the Shipping Industry:
Further research should investigate the social implications of AI adoption in the shipping industry. This includes examining the impact of AI on the workforce, job roles, and skills required in the sector. Understanding the social dynamics, ethical considerations, and potential inequalities arising from AI implementation can provide valuable insights into ensuring a socially sustainable transition.

Convergence between AI and Distributed Ledger Technology (DLT):
The intersection of AI and DLT presents promising opportunities for advancing sustainability in the shipping industry. Future research should explore the synergies and challenges of integrating AI and DLT, particularly in areas such as supply chain transparency, traceability, and data sharing. Investigating how AI can enhance the security, efficiency, and trustworthiness of DLT-based systems can unlock new possibilities for sustainable practices.

Empirical Data on the Benefits of AI in the Shipping Industry:
While this study provides insights into the potential benefits of AI in terms of economic and environmental sustainability, further empirical research is necessary to validate and quantify these advantages. Conducting case studies, data analysis, and performance evaluations on real-world AI implementations in shipping operations can generate robust empirical evidence. Such research can contribute to building a compelling business case and facilitating informed decision-making regarding AI adoption.

Collaborative Initiatives and Knowledge Sharing:
Promoting collaboration and knowledge sharing among industry stakeholders, academia, and policymakers is essential to advance the field of AI in the shipping industry. Research should explore the establishment of collaborative initiatives, consortiums, or platforms that facilitate the exchange of best practices, lessons learned, and emerging trends. Such initiatives can foster innovation, standardization, and cooperation, driving the sustainable development and widespread adoption of AI technologies.

Critique against AI regarding security:
This recommendation urges further research on the critique against AI in security, emphasizing the need to address potential risks and vulnerabilities. By considering ethical dimensions and implementing robust safeguards, we can foster a secure and responsible AI ecosystem.

Key Areas of Critique:

Adversarial Attacks: Investigate vulnerabilities of AI systems to manipulative exploits.
Privacy Risks: Examine implications of AI-powered surveillance and data privacy.
Bias and Discrimination: Explore AI algorithmic bias in security applications.
Systemic Vulnerabilities: Assess AI system susceptibility to exploitation and failure.
Accountability and Transparency: Investigate mechanisms for ensuring responsible AI deployment.
Human-Centric Design: Prioritize human values, safety, and well-being in AI development.
Collaborative Efforts: Encourage interdisciplinary collaboration among experts.
Public Awareness and Education: Promote understanding of AI security risks.

Further research is necessary to understand and mitigate the critique against AI in security. By addressing risks, vulnerabilities, and ethical considerations, we can ensure the responsible integration of AI.

By exploring these recommended areas of research, the understanding of AI's impact on sustainability in the shipping industry can be expanded, leading to actionable insights and evidence-based decision-making. The outcomes of these research efforts can contribute to shaping a more sustainable and efficient future for the shipping industry and help guide the implementation of AI technologies in a responsible and beneficial manner.

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APPENDIX A: PRELIMINARY INTERVIEW QUESTIONS

1. Can you tell us about your company's use of AI technology in your operations?

2. How has the implementation of AI technology affected the sustainability of your business model?

3. Can you give us some specific examples of how AI technology has improved your sustainability efforts?

4. How has the integration of AI technology affected your company's overall efficiency and competitiveness?

5. What is your view on the future of AI technology in the logistics/maritime industry and its potential to support sustainable business models?

6. Have you encountered any challenges during the implementation of AI technology in your company, and how have you overcome them?

7. How has your company ensured ethical use of AI technology in your operations?

8. Can you share any plans or initiatives your company has in place to continue incorporating AI technology into your sustainable business model?

9. How has your company involved stakeholder groups, such as employees and customers, in the implementation of AI technology in your operations?

10. How does your company measure the success of AI technology in terms of its impact on the sustainable business model?

11. What is your outlook on the future of AI in shipping?

12. Which segment within the maritime industry do you see the most potential for development with the help of AI?

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