CHALMERS

Managing a sustainable transition in the shipping industry

A theoretical framework proposing strategies for shipping companies to meet future requirements

Bachelor's thesis in Industrial Engineering and Management

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Hantering av en hållbar omställning inom shipping branschen

Ett teoretiskt ramverk för shippingbolag med föreslagna strategier för att möta framtida krav

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SUMMARY

The shipping industry is of high strategic importance for the world's supply chains and the industry is essential for global trades to be efficient and economically beneficial. On the other hand, the industry is also a major cause of global warming. The volume of freight transports has increased globally, and this is a continuous trend, which also increases the environmental impact of shipping. To counteract this trend there are actors such as the International Maritime Organization (IMO) but also other external actors such as banks and regional regulators that set up goals and regulations in order to reduce emissions. To achieve these goals or cope with the requirements companies need to act and reduce their environmental impact. This could be done either by discovering alternative means of propulsion or being more operationally efficient by for example implementing new technology or innovation. This thesis therefore aims to provide an overview of alternative propulsion, strategic and operational decisions, and new technology by mapping, evaluating, and comparing these technologies and strategies for industry actors to be able to follow the increased requirements. Both the environmental and the economical perspective is discussed.

The thesis is conducted via a literature study where relevant literature was examined, providing an overview over what strategies and propulsion alternatives that exist. These were then evaluated and compared between the existing options from a technological, economic, and environmental perspective. Complementary to the literature study, an interview study was conducted. It consists of six interviews with 3 different types of actors, three shipping companies, two marine technology companies and one professor in Mechanics and Maritime Sciences. The approaches for companies to reduce their emissions that are discussed are biofuels, hydrogen, ammonia and methanol, marine gas oil (MGO) and liquified natural gas (LNG), wind-assisted ship propulsion (WASP), battery-electric, leadership, shipowner strategies, innovation strategy, dual fuel engines, interfirm collaboration, industry 4.0 and big data analytics, autonomous shipping and improved information and communication systems.

The thesis shows that it is highly uncertain which propulsion alternatives will be dominant in the future. All the investigated alternatives share uncertainties and have different strengths and weaknesses making this specific question very complex. To be flexible and ready when the technology is mature enough it is important to prepare for the future. In the short term it is of more importance focusing on efficiency improvements both organisationally and with new technology in order to reduce emissions. The suggestion for companies is therefore focusing mainly on efficiency improvements in the short term while in the long term focusing on the combination of efficiency improvements and alternative propulsion.

Keywords: Shipping, maritime transportation, strategy, innovation, technologies, Industry 4.0, efficiency improvements, propulsion, regulations, business model, transition, sustainability

Note: The report is written in English

SAMMANFATTNING

Sjöfartsnäringen är av stor strategisk betydelse för världens värdekedjor och branschen är avgörande för att global handel ska vara effektiv och ekonomiskt gynnsam. Samtidigt är industrin också en stor orsak till den globala uppvärmningen. Volymen godstransporter har ökat globalt och denna trend fortsätter vilket i sin tur även ökar sjöfartens miljöpåverkan. För att motverka denna trend finns aktörer som Internationella sjöfartsorganisationen (IMO) men även andra externa aktörer som banker och regionala myndigheter som sätter upp mål och regler för att minska utsläppen. För att nå dessa mål eller klara av kraven måste företag vidta åtgärder och minska sin miljöpåverkan. Detta kan göras antingen genom att undersöka alternativa framdrivningsmetoder eller genom att vara mer operativt effektiva genom att till exempel implementera ny teknik eller innovation. Detta kandidatarbete syftar därför till att ge en översikt över alternativ framdrivning, strategiska och operativa beslut och ny teknik genom att kartlägga, utvärdera och jämföra dessa teknologier och strategier för att branschaktörer ska kunna följa de ökade kraven. Både det miljömässiga och det ekonomiska perspektivet diskuteras.

Kandidatarbetet genomförs via en litteraturstudie där relevant litteratur granskats, vilket ger en överblick över vilka strategier och framdrivnings alternativ som finns. Dessa utvärderades sedan och jämfördes mellan de befintliga alternativen ur ett tekniskt, ekonomiskt och miljömässigt perspektiv. Som komplement till litteraturstudien genomfördes en intervjustudie. Den består av sex intervjuer med tre olika typer av aktörer, tre rederier, två marinteknik företag och en professor i mekanik och sjöfartsvetenskap. Tillvägagångssätten för att företag ska kunna minska sina utsläpp som diskuteras är biobränslen, väte, ammoniak och metanol, marin gasolja (MGO) och flytande naturgas (LNG), vindassisterad framdrivning (WASP), batteri elektrisk framdrivning, ledarskap, ägarstrategier, innovationsstrategier, motorer som kan ta emot flera bränslen, samarbete mellan företag, Industri 4.0 och dataanalys, autonoma fartyg och förbättrade informations- och kommunikationssystem.

Rapporten visar att det är högst osäkert vilka framdrivnings alternativ som kommer att vara dominerande i framtiden. Alla de undersökta alternativen har osäkerheter och det finns olika styrkor och svagheter, vilket gör denna specifika fråga mycket komplex. För att vara flexibel och redo när tekniken är mogen nog är det viktigt att förbereda sig för framtiden. På kort sikt är det viktigare att fokusera på effektivitetsförbättringar både organisatoriskt och med ny teknik för att minska utsläppen. Förslaget till företag blir därför att främst fokusera på effektiviseringsåtgärder på kort sikt samtidigt som man på lång sikt behöver fokusera på kombinationen av effektivitetsförbättringar och alternativa framdrivningsmetoder.

Nyckelord: Sjöfart, Sjötransport, strategi, innovation, teknologi, Industri 4.0, effektivitetsförbättringar, regleringar, affärsmodell, omställning, hållbarhet

Notera: Rapporten är skriven på engelska

Preface

This Bachelor's thesis was carried out in the spring of 2022 at the Division of Innovation and R&D Management at the Department of Technology Management and Economics at Chalmers University of Technology in Gothenburg, Sweden. The work comprises 15 credits and is the final part of the bachelor’s degree in Industrial Engineering and Management and Mechanical Engineering.

We would like to thank all the people who have chosen to participate in interviews, you have contributed with valuable insights and interesting perspectives. This has helped us obtain an understanding of a very interesting industry in transition, and without you this report would not have been possible. A special thank you to our contacts at Stena AB and the Swedish Shipowner Association, Anna Forshamn and Anders Hermansson, for advice and pointing us in the right direction.

Finally, we would like to thank our supervisor Carl Sjöberger, Doctor of Philosophy and Master mariner at the Department of Technology Management and Economics as well as ambassador for maritime operations in the maritime cluster in western Sweden, for his guidance, expertise, and encouragement. It has truly been invaluable for this work.

Thank you!

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1. Introduction

Shipping is widely regarded as the backbone of global trade and economy and has been throughout modern history (UN, 2016). During the 1950s, there was a growing demand for cheaper fuel, which led to the change from coal to the use of heavy fuel oil (HFO) (Takahiro, 2021). Currently, 70 years later, most large merchant ships are still using HFO as fuel. Following the negative environmental impact that HFO has, the International Maritime Organization (IMO) has introduced regulations to lower the impact (Takahiro, 2021). For instance, regulations from IMO have continually been tightened regarding the sulphur content (SO_x) in fuel oils, from 4,5% to 3,5% in 2012, and to 0,5% or less in 2020 (IMO, 2020b). Similar regulatory actions have been taken regarding the emission of nitrogen oxides (NO_x) and overall, the environmental impact of HFO has gradually been reduced consequently. Yet the pollution from HFO is not limited to sulphur and nitrogen oxides. IMO has also called for a reduction in emissions of greenhouse gases (GHG) in the shipping industry, which is emitted by using HFO. For instance, IMO calls for a reduction of 50 % in GHG emissions by 2050 in comparison to 2008's emissions (IMO, 2020a). This has started to shift the demand for marine fuels, from the ones with the lowest price to those that are environmentally sustainable (Takahiro, 2021). As a result, more and more actors in the shipping sector are looking for alternative means of propulsion than fossil fuels. Transitioning to a sustainable business model that can achieve the coming environmental goals, while still managing an economically profitable business, is a challenge for all companies in the shipping industry.

1.1. Background

This chapter explains the importance of the shipping industry worldwide while also describing the negative environmental impact caused. It also explains how some business models hinder the transition to environmentally sustainable shipping industry.

1.1.1. Shipping Industry and Environmental Problems

The shipping industry is essential and strategically important for global trade ensuring the functioning of the economic supply chains (European Environment Agency, 2021). In an economic region such as the EU, maritime transport handles 77% of external trades and 35% of internal trades which accounts for 50% of the total value of trades (European Environment Agency, 2021; International Chamber of Shipping, n.d.). While shipping is strategically important and has a positive contribution both economically as well as socially, it is also a significant cause of global warming and harms marine ecosystems (European Environment Agency, 2021).

The shipping industry accounts for 11% of the global carbon dioxide (CO_2) emissions in the transportation sector (Statista, 2021). As transportation is one of the biggest contributors to GHG emissions, shipping accounts for a total of 2-3% of global carbon emissions, equalling Germany, the sixth-largest emitter of GHG in the world (Dalli, 2021; IMO, 2020a).

Only 13% of the world's oceans can today be classified as marine wilderness, and shipping is one of the major causes of this (Jones et al., 2018). These areas maintain high levels of ecological and evolutionary connectivity which makes them well placed to recover from climate changes and pollution. Emissions from the shipping sector also contribute to water acidification and changes in nutrient and oxygen levels (European Environment Agency, 2021). For example, the shipping industry causes 16% of the total amount of SO_2 emissions harming human health and the environment.

Both the European Green Deal of the European Commission and the United Nations Agenda 2030 promote a modern, resource-efficient, and competitive economy (European Environment Agency, 2021). The shipping industry is one of the most important industries in ensuring these goals can be achieved. By 2050, the goal is for all industries to be carbon neutral. However, the IMO stated that the target of decreasing GHG emissions by 50% in 2050 is more realistic for the shipping industry (IMO, 2020a). To succeed with this, IMO has developed GHG emission standards for companies targeting both existing and new ships.

1.1.2. The environmental impact of heavy fuel oil

HFO is the residue that is leftover from oil refining processes (Comer et al., 2017). It is extremely vicious and needs to be heated to about 130°C for it to flow in an engine. It usually contains high amounts of sulphur compared to other oil fuels and heavy metal impurities. HFO is considered one of the most polluting fuels, emitting high levels of different air pollutants. For instance, SO_x, NO_x, and climate pollutants, including CO_2, nitrous oxide (N_2O), and particulate matter (PM) such as black carbon. PM is the second largest contributor to human-induced climate change, after CO_2. The dark colour of PM allows particles to absorb a large proportion of the incoming solar radiation which contributes to global warming (Comer et al., 2017).

1.1.3. Current business models

The shipping industry has fewer patent solutions applied than other transportation sectors and the actors are regularly implementing technology, especially digital ones, and techniques first implemented in other industries (Wiśnicki et al., 2021). Today the implementation of new technologies in shipping has been carried out as an incremental innovation process for a long time, and there is no model for the process of adoption of new technologies.

In IMO's GHG standard it is stated that the international shipping sector needs to implement the usage of new technological innovations or energy sources to achieve the overall ambition (IMO, 2020a). Dalli (2021) declares the importance of adopting the new technologies at the right time to ensure growth in the market which can secure the company's future in the industry. However, there are currently a lot of dissents about which technologies are going to get global acceptance and will be dominant in the future. Therefore, it is of great importance to investigate how the conservative shipping industry can transition to becoming a sustainable industry.

1.2. Purpose

This thesis examines how companies in the shipping industry are being challenged by the increased requirements for sustainability. The main aim is to investigate how shipping companies manage the transition to becoming environmentally sustainable. It also aims to study new technologies and fuels from the perspective of profitability, environmental sustainability, and technical performance. Ultimately, this will result in a recommendation for how companies in the shipping industry can develop a successful and sustainable business model. This is in order to tackle current and future issues regarding environmental sustainability while at the same time remaining profitable.

1.3 Problem definition and research questions

An important part of the transition to becoming environmentally sustainable is to investigate alternative means of propulsion. There are a lot of factors to take into consideration for the new options such as cost, availability, reliability, and risks. For the propulsion alternatives to to be seen as viable substitutes, they need to be compared with the current dominating fuel, HFO, cost and performance-wise. This concludes the following research question.

1. Which propulsion alternatives exist for a sustainable transition in the shipping industry?

Transitioning into new propulsion is one part of the transition. However, other actions could have a substantial impact if companies in the industry are to become more sustainable. To identify such actions and identify what focus areas and strategies companies could adopt to transform their business model. Mapping out these focus areas is important for companies in order to know where to put their funds and efforts. Therefore, the following research question will be examined.

2. What focus areas are important for companies to adapt their business model for a sustainable transition?

The implementation of new digital technologies could substantially improve the future of shipping both from the economic and environmentally sustainable perspective. Alternatives for future and current improvements need to be addressed and what impact they can make. Uncertainties regarding digital technology and how companies should manage it is something they need to be aware of when determining if it is worth the effort to develop and implement it. This leads to the following research question.

3. How can the adaptation of digital technologies help the transition to becoming more sustainable?

Different actors may have different requirements for increased sustainability. In order for companies to know which requirements they need to approach; these need to be mapped out.

Furthermore, companies need to know how to address the requirements successfully and adapt their business model accordingly. This is compiled in the last research question below.

4. Which actors have requirements for increased environmental sustainability and how can companies cope with and adapt their business according to these sustainable requirements?

1.4. Limitations

The thesis will be limited to examining shipping and marine technology firms in Scandinavia which can influence the thesis findings. However, to answer the research questions literature from other regions of the world will be used since many solutions are applicable worldwide. Because of the need for a broad look at many different technologies that the purpose demands, different technical aspects are not discussed in detail. Mechanical efficiency improvements such as optimising the hull construction in order to reduce emissions will not be covered either.

The paper will mainly cover air pollution that contributes to global warming. Sea discharge and its effect on marine life will not be discussed extensively. This is due to the current focus in the shipping industry on reducing GHG, as well as selected interviewees and research questions.

1.5. Sustainability goals

Over 25 years ago, author John Elkington coined the term “triple bottom line” (TBL) (Kraaijenbrink, 2019). The point of the term was to emphasise how modern companies must broaden their focus on value creation, steering away from the capitalistic tunnel vision of profit. TBL works as a framework to analyse how sustainable a company is from a social, environmental, and economic standpoint. Today TBL works as a foundation for the 17 sustainable development goals (SDG) adopted by all United Nations (UN) states in 2015. The action plan, known as Agenda 2030, consists of the 17 goals and partly aims to establish strategies to reduce inequality and improve worldwide health, and education levels (UN, 2015). Furthermore, it is a foundation for tackling climate change and preserving forests and oceans.

SDG 17 which focuses on strengthening global partnerships for sustainability is the broadest of the SDGs as it ties into almost every other issue (UN, n.d.). For the shipping industry, sub-SDGs 17.6, 17.14, and 17.16 are the most prominent. The three calls for knowledge sharing of science, technology, and innovation, coherent government policies, and multi-stakeholder partnerships. Important actions to achieve SDG 17 in the shipping industry are to establish shipping-specific sustainability policies through the IMO as well as to support collaborative initiatives that are industry-specific (Norwegian Shipowner Industry & DNV GL, 2017).

1.5.1. Economic

One part of the TBL focuses on maintaining economic growth in companies and ensuring a sustainable financial system for future generations (Miller, 2020). For the shipping industry, focusing on SDG 8 related to decent work and economic growth will have the most impact (Norwegian Shipowner Industry & DNV GL, 2017). Sub-SDGs 8.2 and 8.4 that strive to achieve a higher level of economic productivity and improve resource efficiency worldwide will be important to focus on. The shipping industry must provide affordable and sustainable shipping services to facilitate the growth of the economy and create jobs across industries (IMO, n.d.-a).

1.5.2. Social

Socially robust societies are fundamental to making sure the future is truly sustainable. Two aspects of this are SDGs 11 and 7, having sustainable cities, and providing affordable and clean energy (UN, n.d.). The shipping industry needs to provide safe and accessible transportation (Norwegian Shipowner Industry & DNV GL, 2017). Simultaneously, the industry needs to develop and implement solutions for urban transport with zero emissions. An example from IMO (2022) on how to tackle the issue of clean energy is the Global Maritime Energy Efficiency Partnership (GloMEEP). GloMEEP is a collaboration project between IMO, the Global Environment Facility (GEF), and the United Nations Development Programme (UNDP). The project focuses on developing countries, where shipping is increasingly concentrated, creating global, regional, and national partnerships. The SDG is to address maritime energy efficiency and help countries bring this issue into their development policies and national dialogue (IMO, 2022).

One ethical concern for the shipping industry is corruption, the anti-corruption plan is immature, and the industry has transparency issues (Dahlgren et al., 2019). Corruption in the shipping industry can lead to other illegal and unethical businesses within the companies. Furthermore, the shipping industry is cutting off every possible cost regardless of whether the cost reduction is unethical or not. This can result in a lack of safety and cheap fuel alternatives that are mainly produced in countries with low social sustainability standards (Leong, 2021).

1.5.3. Environmental

SDG 13, Take urgent action to combat climate change and its impacts, needs to be addressed across every industry in all societies. This includes reinforcing resilience towards natural disasters and integrating measures of climate change into national policies, strategies, and planning, as presented by sub-SDGs 13.1 and 13.2 (UN, n.d.). 13.3 also needs to be addressed, aiming to raise awareness and improve education about climate change.

Reducing the emission of GHG in the operations of the shipping industry using alternative fuels is a key to becoming more environmentally sustainable. To achieve this the industry also needs cross-section-specific policies through the IMO and other collaborative efforts (Norwegian Shipowner Industry & DNV GL, 2017). IMO adopted a strategy for the reduction of GHG emissions from ships in 2018, with the vision to phase out GHG emissions rapidly (IMO, n.d.-a). The EU uses the emissions trading system (ETS) as a tool to incentivise reducing emissions. The ETS makes more than 10 000 factories and power plants pay a permit for each tonne of CO2 emitted (European Parliament, 2021).

As the shipping industry operates in oceans across the globe, the connection to SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development is apparent. 14.1, prevent and significantly reduce marine pollution of all kinds and 14.3, minimise and address the impacts of ocean acidification are two key aspects (IMO, n.d.-a). Fostering innovation, introducing policies, and contributing to the clean-up of the oceans are ways in which the shipping industry can succeed in this. Furthermore, establishing requirements for suppliers concerning the entire life cycle is important. It is essential to have global requirements regarding activities such as ship design, construction, and scrapping (Norwegian Shipowner Industry & DNV GL, 2017).

2. Methodology

The following chapter presents the thesis methods to answer the research questions. This thesis uses an approach of exploratory research. The method enables investigating research questions that previously have not been researched in-depth or combined (Swedberg, 2020). The study's research design is to conduct a literature study and broaden knowledge with interviews with different actors within the industry. The section ends with a critique of the selected method of this thesis and a theoretical framework.

2.1. Data collection

In this section, the thesis's two data collection methods will be presented. The data collection consists of performing a literature study as well as an interview study.

2.1.1. Literature study

The purpose of the literature study was to gather knowledge about different propulsion alternatives in the shipping industry and how these might solve and answer the study's research questions. Additionally, methods to become more fuel-efficient and the possible implementation of digital technologies were examined. The literature study has identified the benefits and drawbacks of propulsion alternatives and has also been used to develop relevant questions for the interviews.

Two literature searches in the scientific database, Scopus, were conducted with different search words. Scopus is a well-known database with a lot of scientific publications and was, therefore, the only database used (Murudkar, 2022). After searching with the keywords "(shipping) AND (sustainab*) AND (strateg*) AND (transition)", and "(shipping) AND (sustainab*) AND ("business model")" in publications titles, abstracts and keywords, relevant literature was found. The study focused on publications after 2018 since they are the most relevant for the current situation of the industry. However, older relevant publications, government documents and regulations are being used. The literature study found 115 publications matching the search criteria.

2.1.2. Interview study

Interviews are a suitable method for data collection when exploring more complex issues and when wanting insights from key players within a specific field (Denscombe, 2010). Interviews can be structured differently depending on which subject the researcher is studying. Since the opinions of individuals and companies are of interest to the research questions, a semi-structured interview format was applied. In semi-structured interviews, the interviewee can freely discuss topics that may result in follow-up questions, which can deepen and broaden the understanding of the interviewer (Denscombe, 2010; Lantz, 2007). The interviewee can elaborate on interesting topics, which would not be possible in a structured interview. To minimise the risk of missing out on significant information, the interviews were recorded after being granted permission from the interviewees. Three different interview guides were constructed depending on which type of actor was interviewed and can be found in Appendix 1, 2 and 3.

In the interview study, different actors within the shipping sector were contacted, including shipping companies, marine technology companies in shipping, people from academia and consultants. These actors were contacted via mail and telephone which resulted in interviews with five companies acting within the shipping industry, of various sizes, and with one professor in a relevant area of study. The interviewed companies and the professor are anonymous in the report and will be mentioned as Shipping company 1, Shipping company 2, Shipping company 3, Technology company 1, and Technology company 2 whereas the professor will be mentioned as Marine professor onwards. In Table 1 below, all the conducted interviews are presented, including which company or organisation they belong to as well as the position of the interviewees within that organisation. All seven interviewees work in relevant areas in relation to the purpose of the study and can therefore provide valuable information about the company as well as the industry in general.

Shipping company 1 is a global firm within the shipping industry, focusing on bulk transport around the world, and has an annual turnover of 1.5 billion SEK. Shipping company 2 is a global actor in liner traffic with an annual turnover of 10 billion SEK and Shipping company 3 is a bulk transport firm with a turnover of 150 million SEK. Technology company 1 is a company working as a technical resource for internal companies operating in the shipping industry and helps with different tasks regarding innovation of operations. Technology company 2 is a global firm, working with ship-owners, yards and naval architects providing technical solutions to improve and make ships sustainable and greener with a turnover of 2.5 billion SEK.

Table 1

Description of each interviewed person in the thesis.

Company/Organisation	Interviewee's Position	Date	Length
Shipping Company 1	Head of Data Science	23-03-2022	87 min
Shipping Company 1	Digital Business Developer	23-03-2022	87 min
Shipping Company 2	Network and Business Development	24-03-2022	53 min
Shipping Company 3	Managing Director	29-03-2022	57 min
Marine Technology Company 1	Newbuilding Project Manager	06-04-2022	59 min
Marine Technology Company 2	Business Line Manager	22-04-2022	78 min
Large Technological University in Sweden	Professor at Mechanics and Maritime Sciences	02-05-2022	51 min

2.2. Data analysis

After all interviews and literature were collected, a method for structuring and analysing the data was needed. The 115 publications found in the literature study were sorted out of relevance on a scale of 1 to 3, in relation to the thesis purpose. Of these 115 publications, 25 were graded as highly relevant for this thesis and 38 publications graded as relevant contained valuable information but lacked some aspects of the study's aim in general. The other publications had little or no relevance to the thesis purpose and were therefore discarded. All publications were read by at least two group members to assure the quality of the sorting. This is in line with what Bengtsson (2016) recommends since different researchers might draw different conclusions from the same publications. In the relevant publications, themes, keywords, and concepts were identified. The thesis mostly examines themes and concepts which are in alignment with the theoretical framework, and these will be discussed when comparing fuel alternatives.

The data collected from interviews were analysed with narrative analysis. After transcribing the interviews, themes and patterns were identified from them, which is suggested by Harappa (2021). They argue that narrative analysis is a valuable tool when analysing concepts and theories since it helps researchers to build a deeper understanding of their subject and understand why people act and react as they do. Concepts and themes that were identified from the interviews were then compared and analysed to the themes found in the literature study. Finally, the different themes formed a foundation for which propulsion alternatives, relevant actions, and digital technologies and requirements might have a significant impact on the shipping industry. These actions could be both short- and long-term but also when, if ever, these actions and solutions could be implemented.

2.3. Method critique

Since the thesis primarily looks for data from one scientific database, Scopus, relevant information could be missed. However, this restriction is deemed necessary due to the abundance of information available. In addition, only literature from 2019 and onward will be used which brings the risk of leaving out relevant studies. To cope with this, the thesis will use older relevant sources, with a high number of citations, but will not actively search for them if not needed. The reason for this is to limit the information available but also since older research might be out of date for the relevance of the thesis.

The interviewees are different actors in the industry with various sizes and operating areas. However, since all the companies interviewed have connections to Scandinavia, the interviews might not be representative of the shipping industry as a whole. Furthermore, companies might not want to disclose trade secrets and strategies that can be of interest to the study, which could hinder correct and accurate data collection. To minimise the risk of such a scenario, all interviewed companies are anonymous in the thesis which they were informed of before the interview. Since the interviews were semi-structured, companies can exaggerate their work regarding sustainability in open-asked questions which can be misleading for the authors. To cope with this, potential exaggerated statements were later checked from the company's official sources such as annual reports.

2.4. Theoretical framework

This thesis will in terms of sustainability be based on the theory of TBL explained above. It will mainly focus on the economic and environmental perspectives. The social perspective will be mentioned but not mainly in focus.

This thesis gives an overview of the shipping industry in general by an exploratory approach and is therefore not based on a specific theory or framework. However, the thesis contributes to the scientific fields of strategic management and environmental resource management. It is from this perspective the thesis should be evaluated.

3. Result

The following sections present the results that were found during the literature study and interviews. The data consists of facts about different propulsions, technologies, and strategies as well as a description of how different actors view the work of becoming more environmentally sustainable.

3.1. Fuel alternatives

The transition toward other propulsion alternatives in the shipping industry is a prolonged process (Xing et al., 2021). Therefore, the shipping industry must adopt new technologies early to achieve the emission goals. In this section the alternatives for the shipping industry will be presented and evaluated based on performance, emissions and other aspects of importance will be considered. The identified alternatives are biofuels, hydrogen, ammonia, methanol, marine gas oil, liquified natural gas, wind-assisted ship propulsion, and battery-electric. There might exist additional alternatives for the shipping industry. The identified propulsion alternatives were highlighted in the literature study or in interviews more than once.

3.1.1. Biofuels

There exist numerous types of biofuels that are classified based on the content of the fuel (Xing et al., 2021). Depending on the type of biofuel, there are often differences in the production processes. The oils can be based on leftovers from animals, biomass, or a mixture of both. Regarding vegetable oils, the crops can have various amounts of energy intensity and land area requirements.

Biofuels are free from sulphur in comparison to conventional diesel which generally emits sulphur (Campelo, 2010). One advantage of biodiesel, one type of biofuel, is that it is often feasible to blend with conventional diesel in already existing diesel engines. Biodiesel has lower GHG emissions than conventional diesel since it comes from biomaterials. Compared to conventional diesel, biodiesel has a reduced emission rate of PM and a marginal reduction of NO_x emissions. Energy efficiency for conventional diesel and biodiesel is almost equal. Depending on if engines are adapted to biodiesel or not, the efficiency can be improved. If the engine is adapted to biodiesel, better efficiency can be obtained. Although there exist benefits to using biofuels there are also drawbacks and important aspects to consider if using them. There is also an ongoing debate regarding if biofuels are reducing GHG emissions or not (Morris et al., 2018). The truthful answer does not exist since it all depends on how it is produced. A lot of aspects need to be considered, such as agricultural production and land conversion. It is usual to fail to consider the entire chain of biofuel production.

Brahma et al. (2022) stated that one drawback of biodiesel is the high cost of production, the price is fluctuating based on which oils the fuel is made of. The economic feasibility and sustainability aspect of biodiesel is largely dependent on the price of biodiesel and feedstock availability. Since the population grows, the debate of fuel vs food is a current topic that needs to be considered. This is because population growth will require more food and thus more land area.

Some negative effects of biodiesel compared to conventional diesel are reduced volatilities, reduced oxidation stability, higher demand for feedstock supply and an enlarged demand for water and land resources (Atabani et al., 2012). Biodiesel is relatively well explored and different sectors have started to adopt the fuel in already existing diesel engines, including both blends and 100% biodiesel (Mohd Noor et al., 2018). Examples in the marine sector are Caterpillar, MAN, Wärtsilä and Yanmar who say their engines can run on biodiesel in their engines without modification.

Aviation is an example of an industry that will require a large amount of biofuel in the future, leading to higher demand (Köhler, 2020). This increased demand will result in an expansion of the infrastructure for biofuels. The development of the infrastructure will in turn reduce the cost of production and lower the price. However, the increased demand from many industries can also result in an increased price which will have negative effects on the shipping industry's ability to use biofuels in the future.

Shipping company 2 stated that biofuels are relevant for their transition towards more sustainable propulsion alternatives. However, building new ships that can only be driven by biofuels is not relevant. More relevant are vessels with dual-fuel engines that can be driven by various fuels, where biofuels are a potential option, as well as other propulsion alternatives. Shipping company 2 continued to explain that biofuels are interesting in the short term but in the technical aspect, it is not mature enough. According to Shipping company 3, the infrastructure for biofuels is not yet well developed and this is one great barrier that hinders their transition. Furthermore, they continued to elaborate on the finite biofuel resources that will not be enough to cover the global need. Another barrier is the high price of biofuels. Technology company 1 stated that biofuels are considered to be an alternative to implement on existing ships now as well as blends. They also pointed out that they do not believe that biofuels will not be used in a large amount in the future.

3.1.2. Hydrogen

Hydrogen has one of the highest energy densities per unit mass, as well as higher combustion energy compared with many other fuels (McCay & Shafiee, 2020). Renewable energy sources have an intermittent energy character and cannot be utilised at all times. This necessitates the alternative to store energy over a long time for the occasions when the energy income is low from the renewable energy income. Therefore, the usage of hydrogen has received significant attention as a potentially suitable energy carrier (Ortiz-Imedio et al., 2021).

Hydrogen can be converted to electricity in a fuel cell (McCay & Shafiee, 2020). A fuel cell is a device that uses chemical reactions between hydrogen and oxygen to produce electricity, only having water as a by-product. However, during the extraction, hydrogen is mainly bound in compounds and not in a free state. This means that other energy sources must be used to separate it. These compounds consist mainly of water, natural gas, coal, or biomass. Depending on which compound the hydrogen is extracted from, the overall environmental impact differs.

Sundén (2019) claims that there are still several challenges regarding hydrogen as a fuel. The cost of producing hydrogen is currently very high. Transportation and storage are laborious, and the number of hydrogen fuel stations today is low but may increase in the future. Due to the low energy density of hydrogen, a higher volume for transportation and storage is required. Therefore, compressed, and liquid hydrogen is necessary for practical applications. Depending on the pressure, between 10-20 times more storage is needed for H_2 compared to HFO (Xing et al., 2021). If the temperature could be lowered in the liquid hydrogen to minus 253°C, the required storage would only need to be 4-5 times larger. High pressure and low-temperature transport and storage mean higher operational costs. This could reduce the competitiveness of hydrogen as a fuel, especially in the case of maritime transport as the storage capacity usually is limited. Technology company 2 claimed that the storage of hydrogen is one big problem that hinders companies from using the fuel in their fleet.

As late as 2021, green hydrogen was more than twice as expensive as hydrogen produced with fossil fuel, and its widespread use was not expected for another decade (Meza, 2022). However, the skyrocketing cost of natural gas has changed the situation and made green hydrogen cheaper than grey hydrogen. This is because the price of green hydrogen correlates with electricity prices and not solely gas prices which is the case for grey hydrogen (Chowdhary, 2022).

Hydrogen can be burned in internal combustion engines (ICE) or converted to electricity in fuel cells (McCay & Shafiee, 2020). The ICE uses the high temperature and high-pressure gases produced by the combustion to produce force, which in turn is applied to components of the engine. Hydrogen can be used in transportation, as raw material in industries or to balance the electric grid. It can also be transported in liquid form by trucks, large containers, ships or as a gas in pipelines or trucks (McCay & Shafiee, 2020).

When hydrogen ICE is compared to the traditional diesel ICE as a fuel in maritime transport with a life cycle assessment, it was revealed that hydrogen ICE has great potential to promote the energy transition (Fernández-Ríos et al., 2022). Hydrogen ICE also presented the lowest environmental impacts. However, the study also claimed that the readiness of the technology is quite low and that the assessment has been conducted at a very early stage. For hydrogen to become more widely developed and deployed, political and stakeholder involvement and collaboration are needed. Technology company 1 is under the impression that 2035 might even be too early for hydrogen widely used in the shipping industry.

Shipping companies 1 and 2 stated that they believe hydrogen will be an important energy source in the future although being very uncertain at the moment. Shipping company 1 further claimed that hydrogen could be practical for short-sea shipping, but the current issue is the low availability of hydrogen. In particular, green hydrogen is not available in high amounts for the shipping industry.

3.1.3. Ammonia

Zero-carbon synthetic fuels including hydrogen and ammonia accompanied by clean production could play a vital role in domestic and short sea shipping (Xing, 2021). However, the current costs and infrastructure are not commercially feasible. Ammonia consists of one nitrogen atom and three hydrogen atoms and can therefore be referred to as a hydrogen carrier. Ammonia has a high energy density and higher boiling point in liquid form compared to hydrogen and can also be burned using a regular diesel engine after proper modifications (Bicer & Dincer, 2018). Shipping company 2 explained that they believe that they have ordered their last conventional ship. Ships with regular diesel engines would instead be dual-fuel, potentially with ammonia as the other option for propulsion.

Ammonia may be classified as either grey, blue, or green (The Royal society, 2020). Green ammonia or production is where the process of making ammonia is 100% renewable and carbon-free. Grey ammonia consumes a lot of energy to produce and emits carbon emissions into the air, often using fossil fuels as feedstock. Blue ammonia is where the carbon emissions produced are captured and stored. The most common type of ammonia production is to first produce the hydrogen using steam methane reforming, which is not an environmentally sustainable method. The hydrogen is then mixed with nitrogen, using energy-intensive methods that contribute heavily to carbon emissions.

Fuel cell systems that are based on grey ammonia and grey hydrogen are not sustainable from an ecological perspective (Perčić et al., 2022). From a profitability perspective, a transition from diesel would not be preferable. If ships with diesel engines are not considered, the second most profitable alternative is blue ammonia. There are barriers to transforming into blue ammonia since the investment costs are high due to the need to change equipment and components.

Technology company 2 explained that ammonia is considered a viable future fuel. They further stated that there are several challenges for ammonia to be feasible. For example, ammonia modified engines are in its development phase and concerns such as toxic waste, and problems with handling and logistics need to be addressed. However, the capacity to produce ammonia exists today, but not in the green classification. Shipping company 3 agreed that if they were to use ammonia, it must be green to not be seen as pointless.

Shipping company 1 claimed that there is not any ammonia powered ships to buy yet. Of the total 3 700 ports worldwide, 192 are right now equipped with ammonia infrastructure, which is not nearly sufficient for the current demand (Magnusson & Murphy-Cannella, 2021).

3.1.4. Methanol

Renewable methanol appears likely to be the most promising alternative fuel for global shipping instead of other carbon-neutral fuel (Xing et al., 2021). With the objective of reaching the 2050 goals for global emissions, consensus building and action-adopting as early as possible is important to reach the targets. Shipping company 2 has a vessel that can operate using methanol with a dual-fuel engine. They also have ordered three methanol ships and will therefore expand their fleet with methanol running vessels. However, Shipping company 2 explained that there is a problem with the price fluctuations of methanol. If methanol is to be produced in an environmentally sustainable way, the price will most likely increase.

A case study showed that one of the most cost-effective fuel alternatives for shipping was methanol when life-cycle emissions of methanol and HFO were done (Hua et al., 2017). This is in line with what the interview study revealed. According to Technology company 2, grey methanol is currently not cost-competitive. In the cases of ships with dual-fuel engines that could use methanol, companies still choose HFO since it is more profitable. Shipping company 3 claimed that the heat value, the amount of heat released during its combustion, is too low for methanol. This is a reason they have not yet considered it an option. Shipping company 2 explained that they believe that they have ordered their last conventional ship. Ships with regular diesel engines would instead be dual-fuel, potentially with methanol as the other option for propulsion.

The global shipping company Maersk has introduced a design, which is scheduled to be in operation at the beginning of 2024, for new methanol powered container ships (Maersk, 2021). This allows 20% improved energy efficiency per transported container, compared to the industry average for vessels of that size. The ship is dual-engine with methanol and HFO. Technology companies 1 and 2 believed that methanol is a viable option for the future if produced in a sustainable way and will most likely be used in dual-fuel engines. They also stated that the infrastructure needs to be developed for the fuel to be considered as advantageous. It is expensive to be the first to start using a particular fuel, so bigger companies such as CMA CGM and Maersk must pave the way and create a foundation. This will build the infrastructure for the fuel and make it more accessible for a wider spread of companies. Currently, 88 of the 100 top ports internationally already have the bunkering infrastructure in place to support methanol fuel (Methanex, 2020).

3.1.5. Marine gas oil and liquified natural gas

Marine gas oil (MGO) is a fuel that currently is the most preferable clean alternative in the shipping industry (Wankhede, 2021). This fuel is a petroleum distillate and comes in the form of light gas. The content is based on 60% aromatics and the sulphur content is lower than HFO (IEA Bioenergy, 2017). MGO is used in diesel engines on ships that mainly operate at medium or low speed.

MGO blended with biodiesel has the potential of mitigating environmental impacts (Yacout et al., 2021). Today it is mainly used to reduce sulphur emissions to keep in line with the regulations. The conventional diesel engines can adapt to MGO with small adjustments and the infrastructure for the fuel is well developed. HFO and MGO have almost the same amount of emissions regarding CO_2 (IMO, 2014). MGO is considered to be cleaner than HFO since it contains less sulphur without modifications. In comparison to HFO, the price of MGO is substantially higher (Zhao et al., 2019). The price for MGO has been fluctuating at the same time as the price for HFO has steadily increased.

Liquid natural gas (LNG) is a natural gas that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport (Laribi & Guy, 2020). It is a fuel alternative that is the best suitable alternative for reducing SO_x, NO_x, and PM emissions. Compared to HFO, LNG reduces GHG emissions by 20-25%, SO_x emissions are reduced by 100% and NO_x emissions are reduced by 80%. Infrastructure in terms of fuelling stations and storage at ports is limited for LNG which results in a barrier to the transition (Yacout et al., 2021).

If the GHG emissions are evaluated for LNG, the reduction would not be enough to mitigate the climate impact (Brynolf et al., 2014). LNG is often considered to be a transition fuel toward future propulsions such as methanol, biofuels, hydrogen, or ammonia (ben Brahim et al., 2019). When life-cycle emission inventories of LNG and HFO were done, a case study showed that one of the most cost-effective fuel alternatives for shipping was LNG in 2017 (Hua et al., 2017).

Shipping company 1 stated that they ordered dual-fuel ships that could use LNG. With the current prices, they are changing to conventional propulsion alternatives since the price increased drastically. Shipping company 2 ordered a ship in 2016 that was “LNG ready”, but the engine can also be modified to other fuel alternatives. Shipping company 3 explained that other actors ordered ships supposed to run on LNG in 2018 since it was considered cleaner. However, since the LNG prices are not cost-competitive, the engines must use diesel instead.

3.1.6. Wind-Assisted ship propulsion

Wind-Assisted Ship Propulsion (WASP) is defined as the use of wind to move a ship forward (Chou et al., 2021). The range of products available are taxonomised in towing kites, suction wings, rigid sails, soft sails, hull sails, rotors, and wind turbines. Towing kites use high altitude wind kites to generate the lift that provides thrust for the ship. Suction wings generate upwards lift similar to that of an aeroplane wing. Rigid sails are foils that can be adjusted to provide aerodynamic thrust. Soft sails are what traditionally has been called sails. Hull sails are hulls that are built to be used as sails by using relative wind and symmetric hulls to generate thrust. Rotors are rotating cylinders that are installed on the deck to generate thrust. Wind turbines are turbines on the deck of the ship that are installed to generate electricity to be used for propulsion.

The thrust that WASP technology can provide depends on three factors, wind speed and the direction of the wind, as well as the performance of the specific implementation of WASP (Chou et al., 2021). All being equal, the higher the wind speed, the greater the thrust generated by the utilised WASP technology. If winds are strong, this in turn results in higher fuel savings and thereby lower emissions. Long-sea voyages are more likely to enable large fuel savings using WASP compared to short-sea voyages, as open water tends to have higher wind speeds. Long-sea voyages also have lower variability in wind speed between different voyages, than short-sea voyages. The impact on thrust, wind direction is dependent on the specific WASP technology, rotors are most efficient with a side wind and towing kites are the most efficient with a tailwind. Different WASP technologies also differ in the range of the angle of the wind they can operate. The west-east wind that dominates the Atlantic Ocean results in significantly different energy savings when using rotors depending on which way the ship is going (Bentin et al., 2016). For instance, the energy savings going between Baltimore to Wilhelmshaven is 36%, and the other way around the saving is 14%, for a specific WASP implementation.

Without any wind, WASP cannot provide any thrust (Chou et al., 2021). Thereby, WASP implementations are used to replace part of the propulsive power generated from fossil fuels. For the total removal of the use of fossil fuels, WASP needs to be used in combination with other solutions. The big drawback of using WASP technology is that its efficiency is highly dependent on the route it operates on. Rotors can save as much as 10-50% of fuel consumption on the route from Buenos Aires to the Western Approaches (Smith et al., 2013), and as low as 1.8-4.7% on the route from Huelva to Alexandria (Comer et al., 2019). However, the rotors used were not the same and thus a straight comparison cannot be done. Towing kites, rigid sails, and soft sails also show similar savings although being dependent on implementation and specific routes (Chou et al., 2021). Implementations of turbines though only save between 1-4% depending on implementation and route. Because of the impact the choice of the route has, the trade pattern of a vessel has a significant impact on the fuel savings a WASP technology can provide and consequently the economic viability of implementation.

Shipping company 1 explained that their ships could save up to 30% of fuel consumption on their routes in the Atlantic, but that less than 5% could be saved in the Asian waters implementing WASP technology. Because of the need for ships to be flexible, Shipping company 1 did not believe that WASP technologies are economically viable yet. Although, one possibility to make WASP technologies viable for implementation in the future is to make them possible to take off and on. The ability to take WASP technologies on and off would mean that the extra mass and space taken up by them only must be sacrificed on routes that are efficient. Shipping company 3 also expressed this as a possible solution. Technology company 2, who are developing a WASP product with similar performance to what Shipping company 1 described, said that the most important problem for WASP technologies to address is to lower production costs. The small energy savings WASP technologies can give even in unfavourable conditions could be enough for implementation, if the cost is low enough. Although the extra logistics needed for take-off and on the WASP implementation would only add unnecessary complexity, Technology company 2 expressed.

3.1.7. Battery-electric

The shipping industry can implement low- or zero-carbon energy solutions to minimise emissions of GHG through new or enhanced technologies (Bach et al., 2020). Technologies need to be developed and battery-electric powered ships can, instead of conventional combustion ships, be a solution for the future. However, the ships must use electricity coming from renewable sources if they are not to emit any GHG (Xing et al., 2020).

Battery-electric ships are being used today, mostly by small ferries (Bach et al., 2020). However, they are almost non-existing in the shipping industry. More knowledge about batteries and upscaling in marine shipping is needed for the technology to be competitive. An issue with current batteries is that they have low energy density which forces batteries on long travelling ships to be large and thereby heavy (Xing et al., 2020). With current technology, battery-electric ships are only feasible on short distances with small ship sizes. KONGSBERG and Yara International have built the world's first electric-powered container ship, which is meant to operate in the coastal region of Norway (Yara, n.d.). For the technology to be applicable for longer shipping distances, more development of batteries needs to be done (Xing et al., 2020).

Batteries are heavily dependent on charging infrastructure in ports and the electric grid (Bach et al., 2020; Xing et al., 2020). The infrastructure needed to charge large ships does not exist in today's ports, which causes reluctance for companies wanting to invest in battery-electric ships. The investments in infrastructure in ports are expensive and it is unclear whether port owners, shipping companies, governments or a collaboration should pay for the infrastructure, according to Shipping company 2. Stimulation of development and usage of battery-electric ships are needed for the market to implement the technology (Bach et al., 2020). Through regulations, subsidies, and implementation of different GHG taxes, the low- or zero-carbon alternative can be competitive. It lowers the perceived risk of investments in battery-electric ships that shipping companies and operators experience.

Shipping company 1 described batteries will not work for their business since they operate in different ports and could not take the risk of being locked to specific routes where charging infrastructure exists. However, Shipping company 2 mentioned that they have battery-electric ships in development that are planned to operate in 2030 at the latest. A different approach is to use a hybrid solution, consisting of batteries and another propulsion. This has already been adopted by Shipping company 3 and is thereby minimising operating costs and reducing emissions. With the use of turbines that charge batteries when ships are travelling downwards on waves and utilising kinetic energy, the company has minimised fuel costs. This peak saving system has worked well for Shipping company 3 with low implementation costs and is one hybrid solution companies can use to minimise fuel usage. Technology companies 1 and 2 mentioned that the potential lack of infrastructure of electricity in ports is one of the biggest problems with battery-electric ships. However, both companies believed that battery-electric ships are technology feasible on shorter distances, preferably with set routes. Technology company 2 further explained that the reason long-distance battery-electric ships are not possible today is due to batteries' energy density being too low.

3.2. Operational and strategic actions for increased sustainability

This section maps out all identified operational and strategic actions for increased sustainability both from the literature review and the interviews.

3.2.1. Leadership

To become sustainable and implement sustainable alternatives in an efficient way, it is important for companies to have strategic and operational leadership to focus on sustainable value creation (Gjøsæter et al., 2021). Although, it has been proven that having good sustainable technology does not create value in itself. Companies with older less sustainable technology could be more sustainable if they have a better way of utilising their resources. Management teams that adopt a sustainable value creation perspective will in the long run benefit from the increased number of regulations due to the incremental costs they currently spend on reducing emissions. Shipping company 3 mentioned that their strategy was still investing to become more sustainable even though they already had fulfilled the industry's general sustainability requirements for 2025.

Technology company 2 also claimed that the operational leadership on the ship itself is extremely important to reduce emissions. The representative claimed that two identical ships, part of the same fleet, could save about 10% on fuel consumption just depending on who is operating it. Furthermore, the representative explained that this assumes that the right technology is provided to the manager in charge. For companies to be more operationally efficient, it is also important to create a company culture that encourages sustainable behaviour and leadership. This can be done by educating the personnel that operate the ship, making them understand that saving fuels has a positive impact both for the operating captain and the company while simultaneously being good for the environment.

3.2.2. Shipowner strategies

Shipping company 3 claimed that companies in the industry face a big issue managing the long development cycles, as ships are built to operate for at least 20 years. With the design of ships improving and materials becoming more robust, the life cycle of ships is constantly increasing. Shipping company 1 explained how the strategy to cope with this problem varies in the industry. Some companies order ships with the possibility to switch to sustainable propulsion in the future, while others focus on what solutions are best right now. An issue with the second approach is that if sustainable fuel becomes cheaper than traditional fuels, it will take time to make the switch for the whole vessel. This is because ship engines are huge and will cost a lot of money to replace. If the cost of conversion is too high, companies adopting this strategy might have to scrape fully functioning ships.

Another strategy that Shipping company 1 used and claimed many actors use as well to reduce the risk of lock-in effects is leasing. This means they sell their ships and then lease them back, turning the company from an asset company to a service company. This can be a good strategy since it is very flexible. If a new type of fuel is prevalent in ten years, the shipping company can lease, or invest, in a ship that uses that fuel instead of having restricted capital in a non-profitable ship. Shipping company 1 owns 20% of their fleet, and by doing that they reduce the risk of lock-in effects.

3.2.3. Innovation strategy

In the shipping industry, there are two parts to the transition to becoming sustainable. One of them is the use of alternative propulsion, and the other being, there are efficiency improvements (Stalmokaitė & Hassler, 2020). Both these factors are vital for companies to create value in a sustainable way. It is also important for companies to have an efficient innovation strategy. Successful firms in this regard have a mix of reactive, active, and proactive innovation strategies. By mixing these types of strategies, companies can work on both parts of the transition while simultaneously reducing risk as well as regulatory, market and technological uncertainties. Shipping company 1 emphasises the importance of focusing on efficiency improvements. However, they are carefully researching what other fuel alternatives there are, enabling a quick change to different propulsion alternatives when the market is mature enough.

There are many methods that shipping companies use for R&D and to introduce new innovations. The strategy can depend on the size of the company. Shipping company 3 pointed out that because they are a small company, they do not have their own research department. Their strategy consists of meeting suppliers at trade fairs and examining competitors. They do not use any consultants but take external help with ship design. Shipping company 3 claimed that innovation in the shipping industry has not increased in the last 10 years, but rather shifted focus towards sustainability and digitalisation. The same trend can be seen in larger firms such as Shipping company 2. Furthermore, Shipping companies 1 and 3 both believed that innovation in the future cannot solely be focused on sustainability since all companies depend on making profits.

Shipping company 1 explained that the most important thing in their innovation strategy is to spread authority amongst co-workers. They work with test-driven innovation that tests hypotheses and iterates. The strategy consists of setting up key performance indicators (KPI) and breaking them down to reach the goal. The company in question did not typically use consultants or externals. Shipping company 1 believed that having a framework and empowering co-workers is the most important thing in innovation. This is the case since everyone knows issues within their field of operations. Every innovation project did not have a set budget as the money spent depended on how big the improvement can be and what savings can be made from pursuing it.

In a similar fashion, Shipping company 2 also explained they do a lot of work internally. The company is also part of a concern that includes a technical company. They operate as a group-wide function that works as a technical resource in their marine-related business areas. This is done by running pilot projects and exploring new collaborations. Shipping company 2 further explained that company acquisition is also part of their strategy to obtain new technologies. The main reason for the acquisition is to be able to provide customers with something the company cannot offer today. Other reasons can be to expand into new geographic markets.

Technology company 1 describes that they work as innovation support for all parts of their mother firm and have no requirement to be profitable, as the benefit is seen in other parts of the group. The representative expresses the importance of having a technology proven solution when it is implemented on the ships. The innovation must pass through many development stages, and be commercialisable, before it is presented to the customer. As customers often do not have the full technological competence to understand the innovation, they will encounter many problems if a non-technology ready product is implemented. Optimising the point when you introduce a new solution is also of high importance. Much of the work done by Technology company 1 is therefore trying to maximise the return of investment by optimising the point of investment.

3.2.4. Dual fuel engines

Because there are many future propulsion alternatives currently being investigated in the shipping industry, uncertainty is high. According to all interviewed actors, continuing to build conventional ships will not be an option in the future. Shipping company 1 and Technology company 2 claimed that since shipping companies generally operate in many different ports, flexibility is extremely important. Dual-fuel engines are being developed and delivered at an increasing pace. Dual fuel engines allow ships to be operated both on new sustainable propulsion, and conventional marine fuels, such as HFO (Wärtsilä, n. d.).

According to Shipping company 2 in the latest years, LNG has been the most widely used fuel in dual-fuel engines combined with conventional fuels. Shipping company 2 introduced a ship in 2016 that was LNG-ready. However, Shipping company 1 expresses that due to price increases, many companies are looking for other alternatives. Methanol is also considered a viable option with Shipping company 1 introducing it into their vessel in the coming years. Shipping company 2 believed that in the future, it might be possible to have more than two propulsion methods present on ships at once. An example of this could be adding a battery in addition to having a dual-fuel engine.

3.2.5. Interfirm collaboration

Another solution to reduce emissions is increasing the amount of interfirm collaboration (Ji et al., 2019; Koilo, 2022). By being more collaborative, companies can take advantage of the mediating effects of innovation and sustainable development. For technological innovation, it is important to have strong relationships with marine equipment manufacturing enterprises to become more energy-efficient (Ji et al., 2019). This will make shipping more economical, energy-saving, and environmentally sustainable. The same thing is also emphasised by the interviewed shipping companies which in some way all collaborate with marine equipment manufacturers to become more sustainable and adopt new innovations efficiently. Technology company 2 claimed that good collaboration with shipping companies is also important from their point of view, often resulting in cheaper and better projects.

There have been some attempts to make collaborative efforts for shipping companies to together improve energy efficiency. A case study showed that an effort similar to this led to improvements but just for already top-performing companies (Borg & Yström, 2019). This means that the already well-performing actors in the field benefit from increased collaboration and it's hard to include the bulk of companies in a similar collaboration. Technical company 2 refers to a similar kind of initiative that had a more concrete solution for successful beneficial interfirm collaboration. The initiative gathered the biggest companies on a national market and divided the potential beneficial innovations among these companies. If one succeeded in developing a useful product all the actors could leverage the innovation. In this way all the companies became the first adopter of something reducing the common cost and preventing a waiting game.

Shipping company 1 claimed that approximately 10-20% of emissions could be cut if general industry regulations would change. Right now, companies in the industry are restricted to contracts with their customers, limiting for instance change of speed and route to make efficient use of currents. Shipping company 1 claimed that if they were able to shift and optimise these parameters companies could keep the same estimated time of arrival but reduce emissions. In this case, interfirm collaboration could push the industry regulations for the companies to collectively reduce emissions. This is also something that both technical companies interviewed confirm. Technical company 2 claimed that the agreements often tend to favour unsustainable solutions such as it is cheaper to be in port and wait for the carrier instead of applying a just-in-time (JIT) strategy. In this way, companies could reduce the speed just before arriving, decreasing emissions. Furthermore, Technical company 1 claimed that the reason behind this is that every part of the supply chain is optimised for every specific portion of it and not as an entire unit. Technical company 1 suggests that a possible solution to this problem is for the carrier to split the cost savings made as a consequence of reducing the speed with the shipping company. In this way, both could benefit from the decrease in speed.

3.3. New technology assisting the transition

It is commonly known that there are two parts to the transition of becoming environmentally sustainable (Stalmokaitė & Hassler, 2020). One is the transition to alternative fuels and the other part is efficiency improvements. This idea is also shared by the interviewed companies, and they all share the common view that efficiency improvements are important in order to reduce emissions.

Digital innovation is a key driver in business change, both in terms of reducing energy consumption and emissions into the atmosphere (del Giudice et al., 2021). However, it remains difficult to make such innovations viable as they are not inherently isolated in their effects and should therefore be created and incorporated holistically into the company. Below specific new digital technologies that could assist the transformation efficiency-wise are presented.

3.3.1. Industry 4.0 and big data analytics

The efficiency improvements are in many ways driven by digital innovation and the phenomena often referred to as Industry 4.0 and have the possibility of disrupting the entire industry (del Giudice et al., 2021; Aiello et al., 2020). The main idea of Industry 4.0 is to create additional value from increased knowledge caused by digitization (Aiello et al., 2020). The term “Industry 4.0” also intends to emphasise the rapid change in how new technology can be leveraged in industry and processes. However, there are still a lot of uncertainties regarding how big of an impact Industry 4.0 will have on the sustainability transition. This is since even though there is a trend to store more information, it is seldomly involved in the decision-making process.

Furthermore, there could be big potential in reducing emissions by implementing big data analytic tools in the industry and it could even be seen as a condition for logistics, in general, to become smart and sustainable (Dalaklis et al., 2021; D’Amico et al., 2021). Managing the increased amount of data in an efficient way to optimise or improve operations will in terms improve the current business model as well as become more sustainable (Dalaklis et al., 2021). The goal of achieving a “data-driven culture” within a company is also pointed out by Shipping company 1. By being a data-driven company, they can react faster to new regulations and requirements since the company knows all the parameters of their operations.

Technology company 2 produces systems which enable data collection on the ship, performance monitoring, and data analysis reports. The system makes it possible to adjust parameters of interest and according to the representative, this is a condition in order to optimise and reduce the fuel consumption. Lowering the variation of certain parameters could, according to the representative, decrease fuel consumption by 3-5%. In combination with how the ship is being operated the decrease could be even more, possibly between 15-20% according to the representative. The company also has a supporting big data analytics tool that could make indirect fuel savings of up to 10% with the right usage. The system provides real-time data on the operational performance providing insights in how to improve operational efficiency and fuel consumption.

Technology company 1 also has an ongoing similar project with a machine learning and artificial intelligence (AI) algorithm for the companies to reduce their fuel consumption. The algorithm takes speed and course into consideration and optimises these variables. According to the company it is still uncertain how big savings of fuel that could be made from this system, but the potential seems to be around 3%.

3.3.2. Autonomous shipping

One important issue that is being discussed along with the ongoing digital transformation is autonomous ships (Shahbakhsh et al., 2021). It is evident that the human role in the maritime industry will be affected by the introduction of autonomous ships, but what role humans will play in the future is still uncertain. The level of autonomy of the ships can vary and depends on how the decision process is constructed. At the lowest degree, the control of the ship is done by the crew with the help of some automated process that the ship can control if needed. Levels 2 and 3 mean the ships can be controlled from another position, with seafarers on board or not respectively. The highest level of autonomously controlled ships, level 4, means a fully automated ship and the decision process being controlled with AI.

An example of an autonomous ship in progress is Yara Birkeland (KONGSBERG, n. d.). Manufactured by Vard Brevik for Yara International, Yara Birkeland is the world's first battery-driven, an autonomous container ship. The ship will start to operate in 2022 and will operate on a 12 nautical mile route in southern Norway. Yara Birkeland will help reduce CO_2 and NO_x emissions by reducing the number of diesel driven trucks driving the same route by 40 000 yearly. Both loading and discharge will be done automatically by electric cranes and have an automatic mooring system. Safety is ensured with three operational centres that can handle emergencies. The centres will also handle condition monitoring, operational decision support, and surveillance of the ship and its surroundings.

Shipping company 2 explained how they work with spreading best practices through an energy-saving program with more than 300 projects. An example is the development of a machine learning program. They also have a project that develops software to help sea captains with route optimization. The assistance can help captains take more parameters into account when operating the ship. This can include handling currents, and avoiding shallow water, and wind. All of which help reduce emissions by making the trip more efficient. Shipping company 1 claimed that by making ships more efficient, shipping companies can save 20-30% of the energy used.

3.3.3. Human elements of automation

Automation is already more prevalent in many industries, such as aviation and the automation industry, which can be helpful for the shipping industry (Emad et al., 2021). With the help of roadmaps, strategy plans and knowledge from other industries, the shipping industry can effectively implement automation more easily. Although much research has been conducted on the technical side of automation, little research has been done on the human element of automation (Shahbakhsh et al., 2021). A key to reaching success for new technology in any industry is making sure workers have the relevant skillsets is considered fundamental (Beechler & Woodward, 2009). For Industry 4.0 this can for example include knowledge of digitalisation.

Furthermore, instead of the human role vanishing with the introduction of autonomous ships, the human role is changing to being more important in the early stages of development (Ahvenjärvi, 2016). This can include activities such as designing and testing the technical systems as well as trying to predict the system's behaviour. The definition of being a seafarer in this new environment will therefore change, with more personnel onshore and new responsibilities (Karvonen & Martio, 2018). There is a need to facilitate the reskilling of seafarers if autonomous shipping is to succeed (Shahbakhsh et al., 2021). Although, some of the skills needed are still unknown. Training content and facilities will also be required. These actions will be important for companies to reduce emissions to reach new regulations, while simultaneously continuing to be profitable.

3.3.4. Improved systems for information and communication

Improved information and communication systems (ICT) between actors involved in ports, as ports themselves and ships, are important for the shipping industry to become more sustainable (de Andres Gonzalez et al., 2021; Fjørtoft & Berge, 2019). A case study conducted in the Central Baltic area where a better ICT system was implemented contributed to higher efficiency, a better JIT approach and timesaving, reductions in transport time, higher transport predictability and improved sustainability and transport quality (de Andres Gonzalez et al., 2021). In general practice Technology company 2 claimed that the current situation in ports makes it favourable to increase the speed just to ensure a place in the potential queue and that JIT thinking is seldomly applied.

There are some challenges in implementing well-functioning ICT systems as they are cross-functional and contain many elements such as trade-related, operation-related, and safety-related elements (Fjørtoft & Berge, 2019). This makes it hard to develop an efficient system but if an efficient system were to be implemented it could make a big impact. There are also some challenges with conducting regulations in parallel with the development of a new system, for example how autonomous ships should be managed. There needs to be a good integration between humans, technology, and organisations in order to adopt some of the new technologies such as autonomous ships (Fjørtoft & Berge, 2019; D’Amico et al., 2021).

3.4. Actors and their requirements for environmental sustainability

In the following section, the requirements that are forcing the shipping industry towards a more sustainable approach will be presented. Both regulations from regulators, as well as requirements from external actors, will be presented, followed by a declaration of how the shipping companies implement the regulations in their current and future work.

3.4.1. Requirements from regulators in the shipping industry

Companies need stricter requirements from regulators in order for them to change their behaviour (Garg & Kashav, 2019). This is to be able to reach IMO's long term sustainability goals of total annual emissions from GHG decreasing by 50% in 2050 compared to 2008 (IMO, 2020b). To be able to achieve this, economic, social, and environmental developments should go hand in hand and must be given equal attention by respective countries (Garg & Kashav, 2019).

Some of the current regulations connected to environmental sustainability within the shipping industry are Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP), and IMO 2020 (IMO, 2020b; IMO, n.d.-b). EEDI is considering the reduction of CO_2 emissions for new ships (IMO, n.d.-b). The regulation is developed to increase the efficient use of engines and equipment. It is done by requiring a minimum energy efficiency level per available capacity on the ships. The regulation is being updated every five years. A low value of EEDI means that the ship has a high-efficiency rate. SEEMP is a measurement focusing on efficiency but compared to EEDI the focus is also considering cost-effectiveness. SEEMP is applied to already existing ships as well as new builds. IMO 2020 is another regulation that was implemented in 2020 (IMO, 2020b). The regulation is considering the sulphur content in the fuels used. The sulphur content requirement has been tightened to 0.5% from previously 3.5% in the fuels that are used in the industry.

Two of the main regulations within the sustainable transition that will be implemented soon are Carbon Intensity Factor Indicator (CII) as well as Energy Efficiency Existing Ship Index (EEXI) (DNV. n.d.-a; DNV. n.d.-b). These will have a major impact on shipping companies. CII is a measurement of the CO_2 emitted in relation to the carrying capacity of the ship (Marine & Offshore, 2021). The ships get a CII rating between A and E annually, where A is the best possible rating and E is the worst. The implications of the CII regulation are that the ships that get the rate E will need to improve their efficiency to be able to continue their business (Lloyd's Register, 2022).

CII is applied to all cargo, RoPax (Roll-on/roll-off passenger vessel) and cruise ships above 5 000 gigatons meaning it affect most of the shipping industry. Technology company 2 stated that CII will be one of the most difficult regulations to maintain since requirements increase every year. Shipping companies will need to improve their ships continuously to be able to maintain the CII rate on their ships during its whole lifetime. Technology company 2 explained that CII will be the most substantial change regarding environmental sustainability in the shipping industry so far.

Compared to the CII regulation, EEXI is a framework that puts a label on ships that it keeps during its whole lifetime without any modifications (Marine & Offshore, 2021). EEXI is a framework regarding energy efficiency within the shipping industry that will take place after January 1, 2023. The framework is applied to vessels weighing over 400 gigatons. In case the ships are included in EEXI, the ship carrier may be forced to modify the ship in order to manage the maximum required levels of emissions. The requirements that are included in the EEXI framework are based on CO_2 emissions and energy consumption.

According to Technology company 2, there are several problems with EEXI. A problem is that the regulation has not been presented yet by IMO and that the regulation is hard to interpret for shipping companies making it difficult for companies to pursue. Technology company 2 further explained that this leads to the shipping companies waiting to address the regulation on their ships causing uncertainties regarding the immediate effects of the regulation. Furthermore, Technology company 1 claimed that it is expensive to be one of the first companies to improve ships since the uncertainties are the largest at this point. Although the cost of transitioning ships towards more sustainable options are high, the Nordic shipping companies interviewed want stricter requirements and regulations in general. Stricter requirements globally are advantageous for shipping companies within the EU since they already have stricter regulations than countries outside of the EU. Stricter regulations would imply more equal competitiveness for all companies globally. Shipping company 3 claimed that right now, the EU has higher requirements than IMO since they think the transition goes too slow. The EU has developed a taxonomy which gives higher interest rates proportional to emission rates.

The interviewed Maritime professor claimed that it is important to formulate the regulations in an efficient way. Previous regulations have not been very efficient, and they have in many cases just shifted the pollution elsewhere. An example of this is IMO's regulation on limiting the amount of SO_x emissions into the atmosphere (IMO, 2016). The intention of this regulation was to speed up the process for companies transitioning to low sulphur fuel instead of the regular sulphur intensive HFO (ICES, 2020). Instead, a technology called scrubbers has emerged which cleans the air emissions from for instance SO_x, transforming the emissions into scrubber discharge water. This water is then released directly into the ocean. These pollutants from scrubber discharge water now exceed those of all other liquid waste streams from ships which was not the initial intention for the regulation.

3.4.2. Requirements from external actors

Shipping companies 1 and 2 explained that their customers currently do not require high sustainability standards and that time of the delivery and availability are more important. Shipping company 2 further elaborated that this results in no pressure for the companies to transition towards becoming more sustainable. One reason that the customers do not require high sustainability standards is a consequence to that the industry mainly is cost-driven. Shipping company 3 explained that their customers are mainly oil companies and that these customers possibly will require stricter standards based on CO_2 emission. There is also a possibility that there will be a carbon tax implemented in the near future in the shipping industry. Shipping company 3 is therefore certain that it will result in higher requirements from the customers since it will be cheaper to emit less.

According to the three interviewed shipping companies another actor that pressures the shipping industry to become more sustainable is the banking sector. Furthermore, all three shipping companies stated that when a new ship is bought, capital from banks is needed in the form of loans. Since ships have a predicted lifetime of more than 20 years, banks have increasingly started to value environmentally sustainable ships for investing. Shipping company 1 claimed that investing in sustainable ships is a safer option for the banks since they are more probable to be able to manage future regulations making the business more profitable. Ships with dual-fuel engines, one of which is a green alternative, tend to receive better funding. Shipping company 2 further elaborated that sustainable alternatives are more likely to receive more beneficial loans.

This is further affirmed by the principles many banks follow. In the year 2018 several banks together drafted the Poseidon Principles which are a framework for assessing the climate alignment of ship finance portfolios (Poseidon Principles, n.d.). The principles are a benchmark and guidance for how a responsible bank active in the maritime sector should behave. The principles are consistent with IMO's ambitions for GHG emission reduction. Today, signatories to the principles make up nearly 50% of the global ship finance portfolio. In 2021, the principles were further extended with a similar set for marine insurance companies. This was done to also promote similar environmental goals from the insurance side regarding the shipping industry.

3.4.3. How the shipping companies use the requirements in their work

Shipping company 1 stated that they have higher ambitions than the current goals from IMO. The company is aiming toward 0% GHG emissions by 2050 while IMO has the goal of 50% less GHG emissions than in relation to 2008's emissions (IMO, 2020a). Due to their customers' unwillingness to pay for sustainability, the transition takes a longer time. Shipping company 2 declares that there exist surcharges for their customers that they can choose to add if they are willing to pay compensation for their trip. They also highlight the importance of optimisation work which in their opinion is a low hanging fruit. Their strategy also consists of continuously using road maps and KPIs to measure and report to the responsible regulators.

Shipping company 3 stated that they would prefer if their customers put more pressure on them regarding the transition towards more sustainable shipping. They work by reducing their SO_x and NO_x emissions and are also measuring the progress to keep in line with the regulations. To cope with future requirements, they build in transformers to be able to use it when the infrastructure for battery-electric technology is ready in ports. According to Technology company 1, a disadvantage with various regulation systems is that it gets complicated for the shipping companies. Shipping company 1 stated that they are ready to act for stricter requirements when needed since they are a data-driven company that can act fast. They continue to declare that they will not act proactively since it is not profitable.

According to Technology company 2, it is key to be able to measure the existing fleet to know where they are positioned now regarding coming regulations. Emissions for the entire year need to be considered and it is also important to try to foresee the rest of the year at an early stage. It is important to be able to change course if needed. The change that could be considered on the ships is then to lower the speed, lower the loading weight, and manoeuvre improvements to reduce the fuel consumption, to be able to fit into the regulations. In the coming time, more shipping companies will need to work with these questions continually and use tools for this in their work.

4. Discussion

The discussion as well as the conclusions are based on insights provided from the literature- and interview study and elaborate on the results from the previous part. The discussion is divided into four parts each associated with the respective research question. The last section will discuss the thesis relevance and suggestion for future research.

4.1. The uncertainty of future propulsion technologies

It is clear from both the literature study and the interviews that there are no alternative propulsion alternatives that clearly stand out as a single solution for the future. The found alternatives all have pros and cons which have made the industry undecided and uncertain about which direction it will take. Actors in the industry are facing challenges to make the first move in switching technologies. Ports around the world can only provide the infrastructure for propulsion technologies that are in use and in high demand from their customers. Similarly, a shipping company is unlikely to invest in a ship that uses a propulsion system that does not have the infrastructure and support it needs in the ports it will visit. This results in a paradox with no current solution.

Of the different alternative propulsion technologies that exist, MGO is one of the most established already (Wankhede, 2021). It already has widespread use, and the infrastructure already exists in most ports which can make MGO a good alternative. MGO also has lower emissions of SO_x and NO_x than HFO. However, MGO has similar levels of emissions of GHG to HFO making the question of sustainability more uncertain (IMO, 2014). If companies are to meet the IMO's goal of a reduction of GHG by 50% in the year 2050 using MGO, a lot of efficiency improvements are needed in other areas to lower fuel consumption. An alternative that shows many similarities with MGO is LNG. An advantage of LNG, however, is that LNG has lower GHG emissions than both HFO and MGO. Although, something to take into consideration is that it is still not close to zero emissions. A problem with LNG is that it is more expensive than the previously mentioned fuels and highly volatile, right now a lot more expensive as mentioned by Shipping company 1. For LNG to become viable the price will probably have to fall or alternatively, the prices for oil rise. A rise of the oil price could artificially be done with regulations.

The alternative fuels that show promise in a lot lower GHG emissions than HFO are biofuels, H_2 solutions, ammonia, and methanol (Campelo, 2010; McCay & Shafiee, 2020; The Royal society, 2020; Xing et al., 2021). Common for all of them is that they have low emissions, both in the aspect of particles like SO_x and NO_x as well as GHG. Nonetheless, a problem with most fuels is that the emissions in some cases could have just been carried over from the operation of the ship itself to the production of the fuel. Methanol can both be produced from fossil sources and from renewable sources (Hua et al., 2017). Currently, fossil methanol is cheaper which leads to it being the most likely to be used by ships constructed for methanol use, as the shipping industry at large is cost-driven. Ammonia and H_2 similarly have a production that consumes a lot of energy and can come from both fossil and renewable sources, which means that the GHG emissions of said fuels de facto depend on where they are produced. This will be an important factor when considering them as alternative propulsion methods for the future of shipping.

Another disadvantage for H_2 if compared to other alternatives is that it has a low energy density and consequently needs large storage tanks that take up a lot of space on the ship (Xing et al., 2021). Ammonia is considerably more energy-dense than H_2, but still requires a lot of space storage if it is to become a viable option. Biofuels on the other hand have large demand from a lot of other transport sectors other than shipping and low production which can lead to increased prices. It is also important to discuss the risk of the increasing price of biofuels since the resources are not infinite. An alternative could therefore be to use biofuels blended with existing fossil fuels. This could decrease GHG emissions to some extent but not entirely at the same time. Right now, the infrastructure is lacking for H_2 solutions and ammonia compared to oil-based fuels as mentioned by Technology company 2. Methanol and biofuels lie somewhere in between the other options.

Electricity currently lacks infrastructure in most ports for widespread use to be able to function as an alternative to other options (Bach et al., 2020). One benefit of battery-electric ships is that they could have very low GHG emissions if the production of electricity is green. However, the batteries that are needed for the storage onboard the ships are very heavy and expensive, and for long voyages would have to be very large. Although, after an initial investment in batteries, the electricity is cheap. This means that if a ship with a battery-electric solution is thought-out to operate for many years, it could be a great investment even if the initial cost is high. All interviewed shipping companies are certain that battery-electric ships can be applicable on short voyages since batteries are large enough to suffice the trip without taking up too much space on the ship. First movers such as Yara Birkeland could be a beginning and an important new step towards a sustainable shipping industry while other actors continuously must develop and innovate new and better battery solutions.

As mentioned by all the interviewed companies, the need for suitable infrastructure in ports where battery-electric ships operate makes it easier to implement them on line ferries that only visit specific ports. These ports can then develop the right infrastructure according to the customer's needs. The application of electric batteries could in the future be used for longer voyages if the batteries are used as a complement to the main fuel source. This would make the ship a hybrid and therefore minimise emissions from the ship. Electric powered hybrid ships have been developed and few are operational and can be a suitable solution for the future. Another solution is that ships could generate a small amount of electricity every time it travels down a wave that could then be used travelling up the next wave which could lead to a more fuel-efficient engine with lower emissions. Shipping company 3 uses this revolutionising technology and has led to more efficient ships and therefore minimising costs and emissions.

Another alternative that can be used to make engines more fuel-efficient is WASP technologies. As remarked by Technology company 2, an advantage for the said alternative is that it does not demand infrastructure from ports and can thereby be implemented independently from what fuels a port decides to provide. However, WASP technologies never replace the main fuel source and can only make a ship more fuel-efficient (Chou et al., 2021). The disadvantage of WASP technology is that the fuel savings only are large enough for the investment on some routes and most ships do not only operate on single routes. As stated by Shipping company 1, Wind could be implemented on some ships effectively but then they are limited in having less flexibility in which routes they could operate on. Similarly, line ferries with favourable standard routes can easily implement WASP technologies in the future. Another solution, that places high demands on port infrastructure, is to make it possible to attach and detach the WASP technology. The technology could then be attached on routes where it is efficient and beneficial.

All the new, promising, technologies have in common that they need investment and innovation to lower production costs. To be able to reach economies of scale that enable low production costs, there is a lot of catching up to do compared with the use of fossil fuels. The economic viability is still a large obstacle for all new technologies.

4.2. Strategy to improve efficiency

There are still a lot of things that could be done organisationally in order to reduce emissions and become more sustainable. These solutions are mostly connected to the efficiency improvement of the transition to becoming sustainable.

In terms of leadership, it is important to consider both operational and strategic decisions (Gjøsæter et al., 2021). An example of impactful operational leadership was raised by Technology company 2, which resulted in a 10% decrease in fuel consumption between two exactly similar vessels. Companies with this focus will have a greater chance of creating value in a sustainable way. An important strategic decision is the innovation strategy, and it needs to both be focused on incremental efficiency innovation and radical innovation such as new propulsion alternatives. Another important aspect of the innovation policy is involving many functions of the company hence the innovations needed are many times cross-functional (Stalmokaitė & Hassler, 2020). The strategy implemented by Shipping company 2 and Technology company 1, having a group-wide innovation function in large firms, can be an effective solution. Working closely with customers and making innovation an iterative process are other strategies that can improve the innovation strategy of the rigid shipping industry. The shifted focus towards sustainability and digitalisation will likely continue and mean technical improvements.

Strategic decisions also involve interfirm collaboration, and, in this regard, it is important to collaborate in the right way. Some industry initiatives have only been useful for already top-performing actors in the industry; hence they are not very effective for the industry in general (Borg & Yström, 2019). Instead, shipping companies should work together against efficiency loss due to regulations in ports and customer contracts. Technical company 2 claimed that another successful way of collaborating could be to divide future innovations between different actors so everyone can take part in the benefits. Furthermore, they claimed that since all actors want to use the new technology, but no one wants to take the first step in developing it, due to the cost, this could be a great way of using the firms' R&D money in an efficient way.

Collaborative efforts could also be made in order for actors in the industry to improve the ports' ICT systems. This would in turn increase efficiency and make it possible to apply JIT thinking which is mentioned to be infrequent by the interviewed shipping companies. Instead, there are currently a lot of incentives towards getting to the port fast and then waiting both as a consequence of lack of communication and due to the conditions on the contracts between customers and shipping companies. This is a condition for the supply chain to become more integrated between actors instead of being optimised in every step of the supply chain which currently is the case. An integrated supply chain could even be favourable for the entire chain if the costs saved because of higher energy efficiency are divided between all companies in the supply chain. A policy like this would favour collaborating with energy-efficient actors which would reduce the total number of emissions.

Shipping company 1 indicated that an effective short term strategic decision for companies could be leasing ships instead of owning them. In that way, companies can reduce the risk of investing in a technology or propulsion alternative that in ten years' time could be irrelevant. When buying ships today it is important to be able to shift propulsion to a sustainable alternative. This could be done by buying a dual fuel engine but also to have the option of later adding WASP technologies or integrating battery-electric technology.

4.3. Technologies to improve efficiency and reduce emissions

Digital technologies are an important part to ensure a sustainable future for the shipping industry. It is important that companies realise the importance of investing in digital technologies and provide resources to further develop them. By implementing elements of Industry 4.0 into the business model, revenue can increase while simultaneously becoming environmentally sustainable (Dalaklis et al., 2021; D'Amico et al., 2021). All companies in the shipping industry should strive to be data-driven, introducing various analytic tools to handle big sets of data to optimise operations in all parts of the business. It could even be seen as a requirement for companies to deal with new regulations carried out by regulators. As explained by Technology company 2, if companies do not know the parameters of their business it is hard to know if they follow the requirements and know what they need to shift in order to follow the requirements. AI technology and machine learning will likely have a substantial impact on the shipping industry in the future. Projects using AI such as the current one by Technology company 1 will become more common and the scope will increase moving forward.

In the future, autonomous shipping is expected to be integrated into the fleet of many companies. However, the degree to which the ships are autonomous will most certainly depend on the route. Companies operating on set routes and on short-sea voyages will be able to use a high degree of automation and self-navigating technology. YARA Birkeland provides an example of what the future might hold, but much research still must be done for fully autonomous vehicles to be an option. Implementation of any type of automation will ultimately result in a new role for seafarers (Shahbakhsh et al., 2021; Beechler & Woodward, 2009). The need for education and reskilling of the humans operating the ships will have to be invested in. Using modern learning methods, like lifelong learning and project-based learning is key in ensuring employers will have the best tools possible (Shahbakhsh et al., 2021). Ignoring the human role in automation will result in a knowledge gap, restraining further progress.

Another important tool to become more sustainable is route optimisation. The main aim of such software is to make every trip the ships make more efficient. By constantly being connected, sea captains will get help to handle unpredictable variables such as currents and wind. Being able to take efficient routes can result in up to 30% less fuel used as explained by Shipping company 2. A condition for efficient route optimisation is providing the optimisation algorithm with correct input data. This makes data collection equally important for route optimisation as any other operational optimisation and therefore this is also a great reason for companies to become data-driven.

By implementing a JIT approach, companies can also become increasingly efficient. This can be done by developing cutting edge ICT systems that help to reduce transport time, increases predictability and result in less fuel usage (de Andres Gonzalez et al., 2021). These systems need to be developed in collaboration with ports and between companies. Big companies have some influence on how the ports are being operated and interviewed Shipping companies 1 and 2 are co-owners of several ports in various locations. According to Shipping company, 1 ports do not have the leverage to change things themselves but if many customers demand change, they will listen. Because this is a potential efficiency improvement for the companies it is a possibility that many companies Together could pressure the ports to invest in and implement improved ICT systems to improve efficiency and decrease emissions. A tricky part of this is the financing which in some way should be divided between all actors.

4.4. Requirements for companies in the shipping industry

As Technology company 1 mentioned, adopting new technologies first is expensive. Even longer transition periods in the shipping industry can occur due to this fact. More well-developed regulation criteria would certainly increase the probability for shipping companies to improve their fleet. If the regulations are formulated in a way that is difficult to interpret, a change in the behaviour of shipping companies is unlikely. Shipping company 2 brought up the dilemma of being an early adopter of new technologies due to uncertainties regarding the maturity of the technology and high expenses. It could also result in severe financial losses to invest in an unproven technology to later realise the industry is moving in another direction. These are some of the reasons that companies do not dare to be the first adopters of new technology.

The reason that the interviewed companies want more regulations is probably because they believe it will bring them competitive advantages. If such a mindset would be favourable the transition could be accelerated. A substantial issue is the fact that the regulations from IMO, who are supposed to be leading the transition, are simply not strict enough. Shipping companies within the EU are getting competitive disadvantages on the global market because the Union has implemented stricter regulations than IMO. In the long term, this can result in problems, both in terms of the global transition and for the specific industry actors affected.

Another disadvantage in the shipping industry is that customers do not require sustainable alternatives at a high rate. One thing that could be improved is that the customers would be informed about their emissions very clearly on every freight. The customers would then be aware and maybe be more willing to pay for the compensation. Otherwise, another solution could be to include the price for compensation in the cost of the ticket. The drawback of such a move could be that other companies that do not have any compensation in the price would benefit.

The pressure the financial institutions can put on the shipping sector should not be forgotten either. The Poseidon Principles initiative shows that multiple actors from the private sector can be bound together to enact change (Poseidon Principles, n. d.). An investment in a more sustainable ship is an investment with a lower risk, which is why banks give them an added value. A single bank would not be able to act alone, since shipping companies with a large environmental footprint could easily just choose another bank. The Poseidon Principles are therefore needed. Similarly, other private actors could be bound together to put pressure on shipping companies. This includes ports, different customer industries and the shipping companies themself. However, for this to happen, everyone needs to see the economic benefit of change, and if it is not present, regulatory instruments are needed in order to accelerate the transition.

As Technology company 2 mentioned, the shipping industry will require higher sustainable standards in the future for every part of the sector. It is relevant to discuss the importance of the stakeholders' pressure on the shipping companies since it will increase due to stricter regulations. Furthermore, stakeholders need to check their whole supply chain and change regulations and competitiveness in the sectors. If the stakeholders within the shipping industry do not require sustainable transportation the transition will probably go slow. A solution could be stricter regulations, but at the same time, it is important to keep the regulations at a global level to maintain competitiveness for companies all around the globe.

It is also important to develop regulations that are not easy to circumvent for shipping companies. If the regulations are not robust, they are not needed at all. If some companies adopt the regulations and do improvement work continuously and other companies just evade them, the companies still have unequal competitiveness. According to the shipping companies interviewed, they work to stay in line with current regulations. They have the tools to change their business but do not, since they are waiting for the regulations to come. Proactive work is poor within the shipping industry since the actors are afraid to lose competitiveness. To increase the willingness to act as well as promote proactive behaviour there must be some adjustments in the sector.

4.5. Relevance and suggestion for further research

The relevance of the study can be motivated by the unique perspective presented in the theoretical framework. This study combines the perspectives of both sustainability and profitability which have during the workflow been discovered to be quite unusual. Many of the articles referred to have chosen to focus on one of these two perspectives. Strategic management and environmental resource management are two fields that seem to go more and more hand in hand, and the literature needs to adjust accordingly. This study has aimed to target both these scientific fields and be an early attempt of combining the two.

In the study, all comparisons and judgements from articles and interviews are based on the author's own observations, making the analysing qualitative. This could be seen as a limitation of the study, but the lack of research and exact reliable data makes quantitative analysis difficult to use in this case. The paper's qualitative analysis makes the findings of the study a guideline for companies to inspire future more in-depth research into the different areas discussed.

In the thesis, an in-depth analysis of the different propulsion alternatives and technologies has not been possible. A proposal for future research could provide more of these analysis methods such as life-cycle analysis and a total cost of ownership analysis of the investigated alternatives. Since the alternatives discussed often are not yet available it is hard to apply these types of analysis, but an attempt is left as a suggestion for future research.

This thesis is primarily a literature study, which revealed interesting insights regarding the entire shipping industry globally as well as in regional areas. Regarding the complimentary interview study, it is based on interviews with companies operating in a global market. However, all interviewed companies are based in Northern Europe. This is mentioned as a limitation of the thesis and therefore it is left as a suggestion for future research, providing a wider spread of companies operating in the industry.

5. Conclusion

In order for a quick transition to a sustainable shipping industry, companies, regulators, and customers need to act and they need to be profitable doing so. Customers are likely to demand greener freight in the future, which will put pressure on all companies active in the industry. Banks are already favouring sustainable options and the pressure is sure to increase. With a higher presence of stricter global regulations, the incentive for companies to act would increase and it would accelerate the transition. This is ultimately the most important factor to ensure a sustainable future for the shipping industry. If regulations differ in various parts of the world, some companies will lose their competitiveness. To meet new requirements, it would be beneficial for companies to cooperate and develop new technologies since it would help the development speed but also assure that individual actors do not lose their competitiveness.

No new fuel alternative is ready to solely be implemented today and it is uncertain which alternatives will be dominant in the future. However, companies can optimise and work on efficiency improvements in their current fleet which can help to lower costs and emissions. Shipping companies could utilise digital technologies such as route- and speed optimisation which has the possibility to have great positive impacts environmentally and economically. Some of the techniques are already in use but are likely to be more prominent in the future. Focusing on innovation will also continue to be an important factor to ensure future competitiveness. Companies in the conservative shipping industry need to invest in the development of new technologies. The efficiency improvements on ships can lower fuel costs drastically which both lead to better financials and makes it easier to cope with regulations. Another solution companies can work on and develop today is education and knowledge. Depending on who is managing the ship the same exact ship can consume different amounts of fuel for the exact same route. With proper usage of human capital, companies can lower their cost even more, consequently making them more sustainable and profitable.

In the long term, efficiency improvements are not enough to meet the increased requirements and fuel alternatives need to be developed. However, all fuel alternatives are not applicable to all ships and routes and individual solutions need to be developed. A problem with many fuel alternatives is that none or very little infrastructure for the fuels exists in ports. It is also unclear who should pay for the large infrastructure investments which slow down the change in fuels. Battery-electric ships can work on shorter distances and in line traffic where the routes are fixed but are not suitable for long-distance shipping with changing routes. For line traffic, it can be easier to build a relationship with the port owners and together invest in the electric infrastructure needed for a technology like batteries. For longer shipping distances, many propulsion alternatives could be used depending on which route a company takes. It is also strongly influenced by which alternatives ports will provide in the future. Biofuels can today be a step towards a more sustainable shipping industry and lower emissions. Investments in dual motor-powered ships with the possibility to easily change to another fuel can be a solution for companies who are uncertain of which alternative to choose. Although, an issue with many propulsion alternatives is that the technical performance today is too low or that the cost is too high to be competitive with current fuels. Ships equipped with WASP technologies could be beneficial for routes with favourable winds and could be implemented on existing ships today.

To get the biggest effect and drive the shipping industry to a more sustainable industry, the new propulsion alternatives need to be combined with efficiency improvements on the ships. When combining the two, emissions can be lowered since less fuel is consumed, making it possible for companies in the shipping industry to meet new requirements from different regulators such as the IMO and the EU.

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Appendix

Appendix 1: Interview template for shipping companies

Value proposition

- What are your company values and how do you work to fulfil them?
- How do you generate value? What differentiates you from your competitors?
- How do you analyse where value is created in your business model?
    - How do you work to cut unnecessary activities?

Fuel alternatives

- Which propulsion alternative(s) exist as a sustainable transition?
- Which fuel alternatives do you think will be the future for your company and why?

Customers

- What are your targeted customer segments and how do you reach them (channels)?
    - Is there a push from the customers for the transition?
    - What do customers value, precise deliveries or lower costs?
    - How do you think your customers will react to temporary higher prices at the start of the transition?
- How is your cost structure constructed?
    - How has this changed when regulations regarding sustainability have been introduced?

Suppliers

- What requirements do you have on your suppliers?
    - How do you analyse them?
    - What are the most important aspects when choosing a supplier?
- What trends do you see in the shipping industry?
    - Is there a push toward more sustainable alternatives?
    - Are you mainly working to mitigate CO_2 emissions or are there other emissions etc. that you are working on reducing as well?
    - What options do you see as reasonable for future energy consumption?

    - What are the benefits and drawbacks of the type of propulsion you are considering and of other types you did not choose?

Sustainability goals

- What are your sustainability goals?
    - How are you planning to reach your sustainability goals?
    - What is your relation to Agenda 2030, the UN's 17 goals?
- How do you measure your results for the sustainability transition?
- Is there any optimization work you are considering in addition to changing fuel/energy alternatives to be more sustainable, e.g. weight optimization, speed limitations?
- From cradle to grave, which are the main challenges with the life cycle of the ships?
    - Can the ships adopt new important technologies, e.g. change of fuel, easily or do the ships need to be newly produced?
- Do you believe your supply chain is sustainable, why or why not?

Innovation

- How do you work with innovation (internal, consultants, acquisitions)?
    - Has the money spent on innovation increased in the last few years and if so, in what focus areas?
    - Are there internal conflicts in regard to where resources for innovation should be allocated?
    - What is hindering you from reaching that goal?

Regulations

- What type of pressure from regulators do you need to transition into becoming more environmentally sustainable?
- What regulations do you expect to see in your sector?
    - How will they change the way you work?

Appendix 2: Interview template for marine technical companies

Value proposition

- What are your company values and how do you work to fulfil them?
- How do you generate value? What differentiates you from your competitors?
- How do you analyse where value is created in your business model?
    - How do you work to cut unnecessary activities?

Fuel alternatives

- Which propulsion alternative(s) exist as a sustainable transition?
- Which fuel alternatives do you think will be the future for industry actors and why?
- Is it hard to predict and suggest which alternative(s) that are to be used in the future?

Customers

- What are your targeted customer segments and how do you reach them (channels)?
    - Is there a push from the customers (shipping companies, shipbuilders, and naval architects) for the transition?
    - Do customers want to save money on fuel-related changes rather than efficiency solutions?
    - How do you think your customers will react to temporary higher prices at the start of the transition?
- How is your cost structure constructed?
    - How has this changed when regulations regarding sustainability have been introduced? Are you gaining customers when harder regulations are introduced?
    - Are customers coming to you and asking for a specific solution or are you approaching customers with solutions to their existing problems?

Sustainability goals

- What are your sustainability goals?
    - What is your relation to Agenda 2030, the UN's 17 goals?
- How do you measure your results for the sustainability transition? Do you help companies measure or do you only message your own contribution?

- Is optimization work more relevant than changing fuel/energy alternatives today? If so, how will the priority be in the future?
- Which optimization actions are most efficient on new older ships compared to newer ships?
- What is hindering a quicker transition, money, knowledge or willingness to change?

Innovation

- How do you work with innovation (internal, consultants, acquisitions)?
    - Has the money spent on innovation increased, both internally and externally, in the last few years and if so, in what focus areas?
    - Can a trend from the customers be seen regarding which solutions they are demanding?
    - Are there internal conflicts in regard to where resources for innovation should be allocated or is your budget solely based on what customers want?

Regulations

- What type of pressure from regulators do you need to transition into becoming more environmentally sustainable?
- What regulations do you expect to see in your sector?
    - How will they change the way you work?
    - Are you gaining from even harder regulations in the industry?

Appendix 3: Interview template for maritime professor

Customers

- Is there a push from the customers for the transition of becoming sustainable?
  - What do the shipping industry's customers value?
  - How do you think your customers will react to temporary higher prices at the start of the transition?

Regulations

- Who is carrying out the different regulations?
- What pressure from governments is needed in order for companies to transition into a more environmentally sustainable approach?
- What regulations do you expect to see in the industry?
- Are there any other external actors pressuring for change?
- How should the regulations be written in order to be effective?

Propulsion alternatives

- Which propulsion alternatives could be an option for the future?
- Are scrubbers an option?

Government pressure

- How can the pressure from the Swedish government to ship more on the sea be managed?

Appendix

Appendix 1: Interview template for shipping companies

Value proposition

- What are your company values and how do you work to fulfil them?
- How do you generate value? What differentiates you from your competitors?
- How do you analyse where value is created in your business model?
    - How do you work to cut unnecessary activities?

Fuel alternatives

- Which propulsion alternative(s) exist as a sustainable transition?
- Which fuel alternatives do you think will be the future for your company and why?

Customers

- What are your targeted customer segments and how do you reach them (channels)?
    - Is there a push from the customers for the transition?
    - What do customers value, precise deliveries or lower costs?
    - How do you think your customers will react to temporary higher prices at the start of the transition?
- How is your cost structure constructed?
    - How has this changed when regulations regarding sustainability have been introduced?

Suppliers

- What requirements do you have on your suppliers?
    - How do you analyse them?
    - What are the most important aspects when choosing a supplier?
- What trends do you see in the shipping industry?
    - Is there a push toward more sustainable alternatives?
    - Are you mainly working to mitigate CO_2 emissions or are there other emissions etc. that you are working on reducing as well?
    - What options do you see as reasonable for future energy consumption?

    - What are the benefits and drawbacks of the type of propulsion you are considering and of other types you did not choose?

Sustainability goals

- What are your sustainability goals?
    - How are you planning to reach your sustainability goals?
    - What is your relation to Agenda 2030, the UN's 17 goals?
- How do you measure your results for the sustainability transition?
- Is there any optimization work you are considering in addition to changing fuel/energy alternatives to be more sustainable, e.g. weight optimization, speed limitations?
- From cradle to grave, which are the main challenges with the life cycle of the ships?
    - Can the ships adopt new important technologies, e.g. change of fuel, easily or do the ships need to be newly produced?
- Do you believe your supply chain is sustainable, why or why not?

Innovation

- How do you work with innovation (internal, consultants, acquisitions)?
    - Has the money spent on innovation increased in the last few years and if so, in what focus areas?
    - Are there internal conflicts in regard to where resources for innovation should be allocated?
    - What is hindering you from reaching that goal?

Regulations

- What type of pressure from regulators do you need to transition into becoming more environmentally sustainable?
- What regulations do you expect to see in your sector?
    - How will they change the way you work?

Appendix 2: Interview template for marine technical companies

Value proposition

- What are your company values and how do you work to fulfil them?
- How do you generate value? What differentiates you from your competitors?
- How do you analyse where value is created in your business model?
    - How do you work to cut unnecessary activities?

Fuel alternatives

- Which propulsion alternative(s) exist as a sustainable transition?
- Which fuel alternatives do you think will be the future for industry actors and why?
- Is it hard to predict and suggest which alternative(s) that are to be used in the future?

Customers

- What are your targeted customer segments and how do you reach them (channels)?
    - Is there a push from the customers (shipping companies, shipbuilders, and naval architects) for the transition?
    - Do customers want to save money on fuel-related changes rather than efficiency solutions?
    - How do you think your customers will react to temporary higher prices at the start of the transition?
- How is your cost structure constructed?
    - How has this changed when regulations regarding sustainability have been introduced? Are you gaining customers when harder regulations are introduced?
    - Are customers coming to you and asking for a specific solution or are you approaching customers with solutions to their existing problems?

Sustainability goals

- What are your sustainability goals?
    - What is your relation to Agenda 2030, the UN's 17 goals?
- How do you measure your results for the sustainability transition? Do you help companies measure or do you only message your own contribution?

- Is optimization work more relevant than changing fuel/energy alternatives today? If so, how will the priority be in the future?
- Which optimization actions are most efficient on new older ships compared to newer ships?
- What is hindering a quicker transition, money, knowledge or willingness to change?

Innovation

- How do you work with innovation (internal, consultants, acquisitions)?
    - Has the money spent on innovation increased, both internally and externally, in the last few years and if so, in what focus areas?
    - Can a trend from the customers be seen regarding which solutions they are demanding?
    - Are there internal conflicts in regard to where resources for innovation should be allocated or is your budget solely based on what customers want?

Regulations

- What type of pressure from regulators do you need to transition into becoming more environmentally sustainable?
- What regulations do you expect to see in your sector?
    - How will they change the way you work?
    - Are you gaining from even harder regulations in the industry?

Appendix 3: Interview template for maritime professor

Customers

- Is there a push from the customers for the transition of becoming sustainable?
  - What do the shipping industry's customers value?
  - How do you think your customers will react to temporary higher prices at the start of the transition?

Regulations

- Who is carrying out the different regulations?
- What pressure from governments is needed in order for companies to transition into a more environmentally sustainable approach?
- What regulations do you expect to see in the industry?
- Are there any other external actors pressuring for change?
- How should the regulations be written in order to be effective?

Propulsion alternatives

- Which propulsion alternatives could be an option for the future?
- Are scrubbers an option?

Government pressure

- How can the pressure from the Swedish government to ship more on the sea be managed?

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