Alternative fuels as an instrument of CSR in shipping industry:
A case study of sustainability and profitability of operating LNG powered vessels

Diploma Thesis

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I would like to thank my supervisor for expert insight, recommendations and great patience; my family for providing moral support during the course of my studies and writing of this thesis, and my friends and schoolmates for making this study journey enjoyable.
Statutory declaration

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Abstract

This diploma thesis formulates recommendations for managerial decision making while acquiring new vessels. It analyses by means of a quantitative research the possible fuel cost savings achievable by running IFO and LNG powered vessels, their benefits and drawbacks in terms of economic, environmental and sociological aspects. Subsequently, Payback Periods and IRR of aforementioned fuel types are calculated and questionnaire data gathered. Hypotheses for the questionnaire research are statistically tested and reveal a relation between customers attitudes to shipping companies and their willingness to pay more for the same service with better CSR strategy. The quantitative research shows LNG as the best fuel option for shipping companies, offering benefits in all three pillars of CSR.

Keywords
CSR, LNG, IRR, Payback period, shipping, profitability, sustainability, questionnaire, alternative fuel, environment

Abstrakt

Tato diplomová práce formuluje doporučení pro manažerské rozhodování při nákupu nových plavidel. Pomocí kvantitativního výzkumu analyzuje možné úspory nákladů na palivo při provozu lodí na IFO nebo LNG, výhody a nevýhody těchto paliv ve vztahu k environmentálním, ekonomickým a sociologickým aspektům. Následně je vypočítána Doba návratnosti a Vnitřní výnosové procento pro výše zmíněná paliva a jsou sbírana dotazníková data. Hypotézy dotazníkového výzkumu jsou statisticky testovány a odhalují vztah mezi názorem zákazníků na rejdajský společnosti a jejich ochotou zaplatit více za stejnou službu od společnosti s lepší CSR strategií. Kvantitativní výzkum představuje LNG jako nejlepší volbu paliva pro lodní dopravu, nabízejíc výhody ve všech třech piliřích CSR.

Klíčová slova
CSR, LNG, Doba návratnosti, Vnitřní výnosové procento, lodní doprava, výdělečnost, udržitelnost, dotazník, alternativní palivo, životní prostředí
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List of abbreviations

LNG – Liquefied Natural Gas
HFO – Heavy Fuel Oil
IFO – Intermediate Fuel Oil
MGO – Marine Gas Oil
CSR – Corporate Social Responsibility
DME – Di-Methyl Ether
ESG – Environmental, Social and Governance
IMO – International Maritime Organization
ILO – International Labour Organization
LPG – Liquefied Petroleum Gas
EGR – Exhaust Gas Recirculation
SCR – Selective Catalyst Reduction
DWT – Dead Weight Tonnage
TEU – Twelve-foot Equivalent Unit
IGF – The International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
BTU – British Thermal Unit
UNCTAD – United Nations Conference on Trade and Development
IRR – Internal Rate of Return
1 Introduction

This chapter introduces the concept of CSR in relevant scope to this thesis, briefly touches on the specifics of shipping industry and specifies the research method, objective and goals of my thesis.

1.1 Overview

While CSR has seen exponentially increasing popularity since 1990’s, it has a fairly long history, which dates back to 1950’s. It can be defined as combination or a set of theories and practices, which influences companies to act in certain ways with accountability to their customers and stakeholders – known as the Triple Bottom Line – Planet, People and Profit balancing out each in the responsible decision making.

Nowadays, we tend to view CSR reporting as a widespread activity among most large companies. However, there are a few business segments and industries, where this activity is limited or missing altogether and shipping industry can be denoted as one of them, with CSR activities virtually non-existent until recent years (Skovgaard, 2011).

In simple terms shipping industry mostly deals with transportation – of passengers and cargo – all around the world. There is of course much more going on in the background – for example logistical operations, which are necessary for the ships to keep going, or insurance. For the purpose of this thesis, it will be dealt mostly with “shipping” in means of transportation, rather than including dozens of various background activities, which support this industry.

A question may arise after reading paragraphs above – why is the shipping industry this late on the CSR bandwagon? It may not be obvious at the first sight, but implementing CSR in the shipping industry comes with many difficulties not experienced by the land-based industries. A ship and its crew are constantly moving from port to port, encountering new groups of stakeholders which come with different sets of CSR related priorities.

According to (Werther & Chandler, 2010) there are five factors affecting the increase of interest in CSR: higher awareness of stakeholders to corporate social ethical and environmental behaviour; direct pressure from stakeholders along with pressure from investors; corporate peer pressure and a greater sense of social responsibility. Furthermore, companies are more aware of the importance of CSR for the image and reputation of the company than ever before. Werther and Chandler continue to discuss that CSR has many benefits for the company, such as improving
financial performance and profitability, lowering operating costs, long-term sustainability for companies and their employees, employee loyalty and motivation, better innovation, good relationships with government and communities, better crisis management, improving brand reputation and value, and developing closer customer relationships and better understanding of their needs.

However, there are views that CSR is not always positive for society – some experts believe that the success of CSR depends on the industry in which the company operates. While there are industries, where are customers generally more appreciative of CSR activities, in other industries (f.e. heavy industries), the customer demand for such companies is much lower.

Shipping industry is known for its low share of companies participating in CSR activities. This could very well be due to low demand or interest in CSR from stakeholders, as well due to very specific set of aspects that is connected with shipping industry. Is it possible to boost the CSR activities of shipping companies by "going green", by using alternative fuels?

1.2 Objectives and aim

The aim of this diploma thesis is to formulate recommendations for managerial decision making of shipping companies while acquiring new vessels with respect to profitability and their CSR strategies.

The aim will be achieved by answering a set of research questions with review of literature and by data analysis and hypotheses testing in later parts of this thesis. The research questions will be divided into two groups with respect to CSR and economic aspects:

CSR aspects:

- What is the reason for lower share of CSR reporting companies in the shipping industry?
- Is it possible to boost this share by using alternative fuels as an instrument of CSR policy?
- Are there any implications against using alternative fuels?
- Are LNG powered vessels sustainable in all aspects of CSR?
Economic aspects:

- Which alternative fuel is most suitable for marine transport as replacement of MGO?
- How profitable are LNG ships in comparison to marine oil powered ones?
- How profitable are LNG powered ships in comparison to HFO with scrubber systems?

Answering these research questions along with data evaluation should gather enough information to formulate accurate, reliable and understandable recommendations for managerial decision making while acquiring new vessels.

1.3 Research Methodology

This chapter introduces the research methodology used in this thesis. It begins with a discussion of various research purposes, followed by different techniques. Next, the research strategy and data collection, sampling and data analysis are selected and described.

1.3.1 Purpose of research

Case studies are divided into exploratory, descriptive, monitoring and causal. These four types will be described below separately.

1.3.1.1 Exploratory study

The exploratory study aims to define research questions and hypotheses for a follow-up study, or determines the feasibility of the desired research process. The exploratory study gathers data in selected area of research. Usually, this kind of study is used to prepare the ground for further studies.

1.3.1.2 Descriptive study

This study creates a full description of the researched matter in the given context and period. These studies are often used where there is already a lot of knowledge about the subject and this knowledge can then be used to categorize the information. Furthermore, this type of study focuses on examining only a few aspects of the broader subject.
1.3.1.3 Causal study

The causal study focuses on data relevant to causation relationships and their consequences. When research and knowledge become even more complex, a causal study may be appropriate. Broad knowledge in the field is required to conduct this study to successfully transfer theory into practice. Also, this study is to outside factors affecting the results, therefore this risk has to be eliminated beforehand.

1.3.2 Research techniques

There are two main research techniques to choose from – qualitative or quantitative.

The main differences between them are the assumptions on which they are built. In qualitative research, data collection is based on “soft” data, such as qualitative interviews. Quantitative research is based on measurement data collection and statistical data.

This thesis is based on both qualitative and quantitative research, as it focuses on questionnaires, calculations and statistical testing.

1.3.3 Sample selection

For the purpose of a case study, it is recommended to select a sample from wide group – regardless of the topic of the research.

1.3.4 Method of data collection

As main methods of data collection can be denoted written sources, observations, interviews and questionnaires. In order to gain better understanding of the researched topic, it is best to use more than one method of data collection. In addition, given the researcher has several different types of data from different collection methods, he can “triangulate” and increase the validity of his research (My-Peer Toolkit, 2016).

1.3.5 Data analysis

This work is partly based on already existing theoretical knowledge of CSR and secondary data.

When conducting a case study, data can be analyzed in two ways – data analysis within the study or cross-analysis. In internal analysis, the observed empirical data is compared to theoretical findings. In the case of cross-analysis, the empirical data obtained are compared with other data from different case studies. As this work focuses on a specific aspect of CSR and one industry and this combination is incompa-rable with other examples, it does not allow to perform cross-analysis, which leaves the only option – to compare empirical data with theory.
1.3.6 Selected methods

For the purpose of this thesis, it was chosen to perform qualitative as well as quantitative research and form a descriptive case study with exploratory aspects. Data will be collected from written sources, observations and questionnaires.

1.4 Structure of the thesis

Introduction

This chapter introduces the concept of CSR and discusses the aim and objective of this thesis. Furthermore, the research methods are described and relevant selected.

Literature review

This chapter is concerned with providing theoretical background of CSR, shipping industry, interconnected issues, available alternative fuels and their implications. It also prepares the ground for analytical part of this thesis.

Analytical part

In this chapter all the data is gathered and evaluated. Current situation is analyzed. Capital and Operational expenditures for ships using MGO, HFO and LNG fuel systems are calculated. Questionnaire data is gathered and hypotheses tested. Outputs of qualitative and quantitative studies are put together to form a coherent whole, so they can be used to formulate recommendations for managerial decision making.

Discussion and Conclusion

This part of thesis summarizes all the knowledge gathered in the literature review and combines it with findings of conducted research and creates accurate, reliable and understandable recommendations for managerial decision making while acquiring new vessels.
2 Literature review

In this chapter, knowledge from various sources will be gathered to understand all the aspects of CSR in scope relevant to this thesis, types of alternative fuels and their specifics will be described and ship newbuilding prices will be established.

2.1 What is CSR

Corporate Social Responsibility (CSR) is an entrepreneurial philosophy which builds the company’s long-term competitiveness on social perception, social performance and sustainable development. It is a voluntary commitment by a business to behave in a responsible manner towards society and the environment, even over a range of legal obligations. CSR strategy includes:

- voluntarily accepting high ethical standards of business;
- minimizing negative environmental impact;
- creating good employee relations;
- supporting the region in which the company operates.

The CSR strategy is based on three basic pillars – economic, social and environmental – which together form the Triple Bottom Line and express key topics and programs, through which the CSR strategy is implemented.

In respect of the “economic pillar” CSR is mainly concerned with fair and transparent relations with business partners – consumers, customers, suppliers, investors – and voluntary keeping to the principles, codes of respective business, keeping due respect for high standards in corporate governance, but also for topics such as intellectual property protection.

The “social pillar” accentuates employee relations, employment principles, willingness to devote part of the profit to philanthropical activities. Key topics include respect for high labor standards, realization of equal opportunities principles, diversity of the workforce and integration of minority groups of employees, inter-generational cooperation, implementation of learning programs and volunteering.

The “environmental pillar” is then focused on reducing the negative impact of business on environment and health of population. Relevant are topics such as emission reduction, energy saving products and services, the use of renewable natural resources or development of products that contribute positively to improving the health of the population (organic products, tracking product origin) (ŽUKAUSKAS, VVEINHARDT, & ANDRIUKAITIENĖ, 2018).
2.2 CSR and financial performance of companies

Multiple studies have found that there is a number of assumptions about the relationship between CSR and company financial performance. (Hill & Becker-Olsen, 2005) argue that if CSR has the ability to influence a company’s reputation, a subsequent impact on the company’s financial performance is also very likely. The views in the scientific community differ, but it is possible to identify main three. In the first case, the assumption is made that investments in CSR shift the company to an economically disadvantaged position compared to less responsible firms. The second is the claim that the net investment costs of CSR are relatively minimal and that companies that invest in CSR are able to actually benefit from this in terms of employee morale and financial performance. In the third case, the cost of investing in CSR on a corporate scale is a significant item but is greatly offset by a reduction in other corporate costs.

While the negative views cannot be easily dismissed, because aside from possibly being put at an economic disadvantage over companies in which such investments are not made, CSR policy can in addition also significantly reduce the strategic alternatives of a company. As an example, it could be needed to avoid dealing with a company which does not follow the same CSR principles or policies. Cases like this can mean reduced financial performance because the company will be forced to choose a less advantageous alternative (Hill & Becker-Olsen, 2005).

Previous research on correlation between CSR and financial performance of the company has yielded mixed results. Experts speculate about the main cause of such variations to be the applied methodology, as it seems to influence the result significantly (Raza, Ilyas, & Rafeh, 2012).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Result</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock price based</td>
<td>Differing or no correlation</td>
<td>Unable to evaluate risk</td>
</tr>
<tr>
<td>Accounting based</td>
<td>Positive correlation</td>
<td>Impossible to exclude effects of other variables</td>
</tr>
</tbody>
</table>

Table 1 Methods of measuring financial performance

While there are only two general ways of measuring the company’s financial performance, there is a big difference between them. However, the economic outcome of corporate involvement in CSR can often be determined by answering “how” and “why” questions in the CSR.

If the company’s goal is to improve its financial performance through CSR, it is likely that investments in CSR will be seen as an alternative to investing in traditional strategies (Raza, Ilyas, & Rafeh, 2012).
2.3 ESG reporting in S&G 500 Index® companies

ESG (environmental, social and governance) is a term used for a set of metrics used by investors to evaluate practices of a company they want to invest in. According to the Governance & Accountability (G&A) Institute research team more than 85% of companies listed in the S&P 500 Index® have published their sustainability reports in 2017. G&A has been conducting this research since 2011 and have found exponentially growing number of ESG reporters (G&A, Inc., 2018).

There is an observable jump in the number of reporting companies from 2011 to 2012 changing the observing firms from minority to majority. This change is mainly driven by increasing demand from investors for comparable, relevant and accurate ESG reports from companies they invest in or want to do so in the future.

For the purpose of this thesis, the percentage of ESG companies (85% for 2017) will be assumed to be the same as the percentage of companies which have developed their CSR strategies and it will be used as a baseline for comparison between shipping industry and market wide average.
2.4 CSR reporting in shipping companies

The views of sustainability and CSR by large companies from other industries were discussed in previous parts. It is apparent that overwhelming majority of companies take part in ESG/CSR activities, because they were able to identify the benefits connected with such undertakings. Let us now take a look at the situation with shipping companies.

According to periodical Shipping CSR500 Survey, which explores the CSR performance across the whole shipping sector, which encompasses shipping companies themselves, loading yards, suppliers, ports, drilling companies and others. As the name suggests, the survey assesses the CSR compliance of 500 companies and organizations according to ISO26000. The Survey revealed average compliance of 52.1% in 2018 and compared to 51.2% in 2017, there is an identifiable positive growth (SAFETY4SEA, 2018). The performance in various factors can be seen in the figure below.

![Figure 2 Shipping CSR500 Survey May 2018 (SAFETY4SEA, 2018)](image_url)
2.5 CSR in shipping industry

As already mentioned above, CSR activities are not as widespread in shipping industry as in others. The assumed reasons why this is the case vary – from economic downturn to shipping being heavy industry or challenges connected with changing groups of stakeholders.

Several aspects of CSR are directly connected or identical with things, that should sit very high on the list of priorities of shipping companies – f.e. health, safety or environment. Since shipping industry is highly regulated (by IMO or ILO) in respect to health, safety and environment, some activities, which would fall under CSR strategies, are already done to comply with legislature. However, CSR should be by its nature performed voluntarily – in addition to legislative requirements.

Shipping industry and its legislative requirements (including CSR implementation) are regulated by four conventions:

- SOLAS (The International Convention for Safety of Life at Sea), IMO
- STCW (The International Convention on Standards of Training, Certification and Watch keeping for Seafarers), IMO
- MARPOL (International Convention for the Prevention of Pollution from Ships), UN
- MLC (The Maritime Labor Convention), UN (Hamad, 2016)

These conventions are trying to provide for level playing field for all companies in the shipping industry and it is possible to say, that shipping industry is among the most developed industries in having a system to globally cover all contract and wage negotiations or industrial relations – a system which is often lacking in other industries on an international level.

Shipping industry has traditionally relied on three pillars: economic, environmental and social aspect – which need to act in synergy. All companies operating in the shipping industry, being it shipping companies themselves, ports, insurance companies or shipbuilders are a part of Chain of Responsibility (see Figure 3) and rely on above mentioned three pillars with the addition of sustainable management systems, training, development, corporate culture and appropriate leadership models (Poulavassilis & Meidanis, 2013).
Alternative fuels for vessels

As per European Union Directive 2014/94, “Alternative Fuels” mean power sources of fuels which can at least partly serve as a substitute for conventional fossil fuels in transportation and have potential to lower carbon emissions and overall environmental impact of transportation.

The use of alternative fuels is key to further development of sustainable transport. Similar to other modes of transport, there is an ever-increasing focus on replacement of conventional fossil fuels in shipping. While this change poses a great challenge for ship design and engineering, the adoption of alternative fuels is unavoidable (due to emission regulations already in effect) and it is expected to have a significant immediate effect – with shipping transport counting for 80% of all trade volume and 3% of global greenhouse emissions. (EMSA, 2018)

Possible alternative fuels for shipping are listed below:

- Liquefied Natural Gas (LNG)
- Biodiesel
- Methanol
- Liquefied Petroleum Gas (LPG)
• Ethanol
• Dimethyl Ether (DME)
• Biogas
• Hydrogen
• Synthetic Fuels
• Nuclear Fuel

All above stated fuels face a common challenge in the form of their physicochemical properties, for example flashpoints, volatilities, energy content per unit of mass or toxicity. The first alternative fuels to be legally regulated and allowed for use are so called low flashpoint fuels, which fall under International Code of Safety for Ships using Gases or other Low flashpoint Fuels (IGF Code) that entered into force on 11th June 2015 (Maritime Safety Committee, 2015).

For the purpose of this thesis, renewable and clean energy sources will be skipped, because of their high initial capital expenditures and generally low efficiency. In addition to this, evaluating profitability and sustainability of these energy sources would provide material for a whole new study. This thesis will concentrate on so called “less polluting fuels”, out of which generally three are considered viable for use in shipping industry:

• Biofuel (Methanol)
• LNG
• HFO with scrubber systems

There are many methods to reduce emissions by increasing efficiency, and although there are very good technologies available, nothing can be considered, as for now, as a solution, rather as a means of support. Most renewable energy sources are nowadays unusable because of inadequate technology maturity or other reasons that do not allow existing fossil fuels to be replaced (Brown, 2018).

2.7 Selecting alternative fuels for research purposes

As mentioned in the chapter 2.6, there are currently only three fuel options considered as viable for use in vessels. In this part, their specifics will be elaborated shortly and the fuels for use in quantitative research of this thesis will be selected.

2.7.1 Biofuel

Biofuel is most often produced from plants or other types of living matter. It is possible to distinguish three basic types – bioethanol, biodiesel and biogas. With ever stricter emission regulations the demand and popularity of biofuels is growing.
The usage of biofuels in shipping industry could reduce CO2 emissions by 80% to 90%, NOx emissions by more than 10% and completely eliminate SOx emissions. Biofuel has a very significant advantage – degradability in water (80-90% in 28 days (Hollebone, 2009)). Other advantages include low additional capital expenditure and relatively simple conversion of existing conventional engines – biofuel can replace fossil fuel without any or with only minor modifications to existing engines.

For the aforementioned reasons, the first ship powered with methanol set sail in 2015, and nowadays more are in operation (Methanex, 2018). Generally, the production costs of these ships are slightly higher than for conventional ships, but they are not as large as the scrubber or LNG. The main issue with biofuels for maritime transport is the low production capacity and the high cost of production, together with some environmental concerns associated with the impact of growing crops used for biofuel production. Moreover, the availability of biofuels in ports is very small and no significant expansion is expected in the coming years (Ship Technology, 2018).

2.7.2 LNG

LNG is currently considered to be the most practical and attractive alternative fuel for shipping. The attractiveness is higher especially for new ships – since the conversion of existing LNG ships is fairly complicated and costly.

Existing research on this subject suggests, that LNG combustion does not produce any SOx and can reduce NOx emissions by up to 90% and CO2 emissions by 25% compared to conventional fossil fuels commonly used in shipping (Amir, Paul, & Walter, 2018).

One of the most important factors contributing to the rise in LNG’s popularity as an alternative fuel for shipping is its low cost. LNG is even cheaper than high sulfur marine oil and significantly cheaper than new low or extra low sulfur marine oils. However, in the case of LNG, the large regional variations in prices must be taken into account. Natural gas reserves are less depleted compared to oil reserves and with the addition of recently discovered natural gas in shale formations the potential reserves have increased exponentially.

The growing popularity of LNG and the advancement of technology contributes greatly to quick construction of storage and refueling stations in ports worldwide. The European Commission has approved a plan to build refueling stations in 139 ports in Europe by 2025 (European Commission, 2013). Given the delivery times of the newly built ships, the lack of refueling stations should not be a problem.

While LNG has undeniable advantages over other alternative fuels, it also brings along some problems. Additional initial capital expenditures are very high (20-30% more than MGO powered ship (Wursig, 2016)) and moreover, LNG must
be stored in its liquid state, which is only possible at temperatures below -162°C – this requires special fuel tanks, which are very expensive and also take up more space in the hull of the ship than ordinary tanks for oil. In addition to this, the uncertainty and hesitation of companies associated with the new fuel system can cause additional problems in the wider deployment of LNG as a ship fuel (DNV GL, 2015).

2.7.3 HFO with scrubber system

HFO and later IFO has always been synonymous with ship fuel. However, over time and with tightening emissions regulations in ports and open seas are these fuels being displaced. Fortunately, there is a way to use these fuels and still meet the emission criteria – scrubber systems.

Unlike LNG systems, a scrubber system is much more suitable for conversion of existing vessels, because it is not as complicated to retrofit and, in this case, the costs are much lower than for LNG retrofit. Installing a scrubber system does not necessitate a modification of existing HFO/IFO engines, nor does it need any changes to the fuel system. For these reasons, HFO/IFO with scrubber systems and exhaust after-treatment are very attractive and best suited for ships already in service (Ählback, 2014).

With the use of scrubber system, SOx emissions can be reduced by 90-95% and NOx emissions by 35-80% with EGR and SCR. Since these systems are designed to operate with HFO or IFO, the installation does not require any additional cost for changes to the engines or fuel system. There are several different types of scrubber systems, but it is possible to divide these into two basic types – wet and dry. Wet scrubbers are further divided into two types based on their working principle – open and closed loop. Open loop scrubbers use sea water, closed loop scrubbers use chemically treated fresh water.

Closed loop wet scrubbers share the same disadvantage with dry scrubbers – the need of additional space in hull of the ship for storing fresh and used water or chemicals in case of the dry scrubber. On the other hand, they share the same advantage – they do not release any waste water back into the sea, unlike open loop wet scrubber, which does. This operating principle of open loop scrubbers is, however, causing an environmental concern and some ports prohibit the operation of these scrubbers. For aforementioned reasons, a combination of the benefits of both wet scrubbers has been developed in form of a hybrid system, which can operate in both open and closed loop mode – open loop is used on open seas and closed loop in ports. The only real drawback of the hybrid systems is its high price, but it is still the best option for most shipping companies (Hansen, et al., 2014).
2.7.4 Selection of fuels for quantitative research

In the analytical part of this thesis, the profitability of running a vessel powered by an alternative fuel will be enumerated. As a baseline for this comparison, costs of acquiring and running MGO powered vessels will be used. MGO is currently the “go-to” fuel for large ships with ever stricter emission regulations coming into force, even though it is 30-40% more expensive than HFO.

HFO was, for a long time, the most widely used fuel in the whole shipping industry (most low and medium speed marine diesel engines used it), with its main benefit being the low price – it is a waste product of crude oil distillation. But because of high sulfur content, HFO is virtually unusable unless the vessel is fitted with some kind of emission abatement system, for example a scrubber – which is a viable option for retrofitting into older vessels to make them conform to new emission regulations. So, HFO with scrubber system will be used as additional option.

The alternative fuel of choice for this research will be, after careful consideration of all factors, LNG. LNG has the many benefits as described above, with the main drawback being the additional capital expenditure while acquiring the vessel. It is already reasonably readily available in ports across the globe and also cheap.

For the purpose of this research, following structure will be used:

- Additional capital expenditure while acquiring a ship
  - MGO
  - HFO with scrubber system
  - LNG

- Running costs
  - MGO
  - HFO with scrubber system
  - LNG

2.8 Ship newbuilding prices and lifespan

According to Clarkson Research, newbuilding ship prices for various vessel types were summarized in the table below. All prices are in USD million and conventional MGO powered ships are considered. It is important to note, that newbuilding prices are very seasonal and change substantially with fluctuating market demand and other factors.
For the purpose of this thesis, it is not necessary to take such seasonal changes into account, because the focus lies on the economic viability of various fuel types, not on the price of the vessel itself.

<table>
<thead>
<tr>
<th>Ship type</th>
<th>Size</th>
<th>Price new</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLCC</td>
<td>320,000 DWT</td>
<td>80,5</td>
</tr>
<tr>
<td>Capesize</td>
<td>180,000 DWT</td>
<td>42,5</td>
</tr>
<tr>
<td>Suezmax</td>
<td>160,000 DWT</td>
<td>53</td>
</tr>
<tr>
<td>Aframax</td>
<td>120,000 DWT</td>
<td>43</td>
</tr>
<tr>
<td>Panamax</td>
<td>80,000 DWT</td>
<td>24,5</td>
</tr>
<tr>
<td>Handymax</td>
<td>65,000 DWT</td>
<td>23,5</td>
</tr>
<tr>
<td>MR</td>
<td>50,000 DWT</td>
<td>33,5</td>
</tr>
<tr>
<td>Container 18,000 TEU</td>
<td>210,000 DWT</td>
<td>144,5</td>
</tr>
<tr>
<td>Container 13,000 TEU</td>
<td>120,000 DWT</td>
<td>109</td>
</tr>
<tr>
<td>Container 10,000 TEU</td>
<td>110,000 DWT</td>
<td>93</td>
</tr>
<tr>
<td>Container 8,800 TEU</td>
<td>100,000 DWT</td>
<td>83</td>
</tr>
<tr>
<td>Container 6,600 TEU</td>
<td>80,000 DWT</td>
<td>60</td>
</tr>
<tr>
<td>Container 4,800 TEU</td>
<td>60,000 DWT</td>
<td>43,8</td>
</tr>
<tr>
<td>Container 2,750 TEU</td>
<td>40,000 DWT</td>
<td>27,8</td>
</tr>
<tr>
<td>Container 1,700 TEU</td>
<td>30,000 DWT</td>
<td>22,3</td>
</tr>
<tr>
<td>LNG tanker</td>
<td>160,000 CBM</td>
<td>182</td>
</tr>
<tr>
<td>LNG tanker</td>
<td>80,000 CBM</td>
<td>70,5</td>
</tr>
<tr>
<td>Pure Car Carrier</td>
<td>6,500 cars</td>
<td>60,5</td>
</tr>
</tbody>
</table>

Figure 4 Price for Newbuilding Ships (June 2017) (Clarksons Platou Project Finance, 2017)

2.9 Fuel consumption by ship size and speed

The fuel consumption of cargo ships can be defined as a function of ship size (DWT) and speed that is exponential at speeds above 14 knots. This can be illustrated by the example of a container vessel with a capacity of 10,000 TEU, which consumes approx. 225 tons of fuel per day. When the speed is reduced to 21 knots, consumption drops by approx. 32% to 150 tons of fuel per day. Of course, all shipping companies would like to minimize fuel costs and thus operate their ships in low speed modes. However, the cruising speed of a ship must also take into account other variables, not just fuel costs – such as shipping times, the need to assign more ships to a given route et cetera.
Nowadays it is possible to identify the following ship speed modes:

- Normal speed (20-25 knots)
  - The optimum cruising speed for which the entire ship was designed - that is, engine, hull and fuel consumption. Most container ships are designed for a cruising speed of 24 knots.

- Slow steaming (18-20 knots)
  - Lower than optimum speed, marine engines run below their full power with better fuel economy. Of course, this saving comes at the cost of longer cruises. However, the difference in consumption is so crucial that since 2011, more than 50% of shipping companies operating container ships are working under this mode.

- Extra slow steaming (15-18 knots)
  - This is an economical speed where maximum fuel economy is preferred over the duration of the trip. This mode is only economically acceptable on certain routes, especially small distances.

- Minimum cost (12-15 knots)
  - Lowest possible cruising speed, as further speed reduction no longer brings fuel savings. This mode is not economically acceptable, even on short routes, so it is unlikely that this regime will be applied to shipping.

Slow steaming was a practice virtually unknown or unprecedented in the global financial crisis of 2008 and 2009. At that time, there was a significant decline in demand in international trade and therefore in maritime transport. Shipowners had to cope with this situation and an increase in the proportion of ships traveling below design speed could be observed in slow steaming mode. This practice has brought several benefits in a time of crisis – reduced fuel consumption, but also the possibility of using more ships on the same routes to maintain the route's transport capacity. Analysts expected that, along with the growing economy, shipping companies would gradually abandon this practice. However, with the benefits of this speed regime which emerged during the crisis continued with it even after the economic crisis – mainly because of rising fossil fuel prices. Thus, from this originally exceptional practice, it became a common standard that customers had to get used to (The Geography of Transport Systems, 2017).
2.10 Benefits and risks connected with LNG in maritime transport

The use of LNG as a fuel in shipping has been very much supported by new emission regulations and by the enormous environmental benefits of LNG over fossil fuels. Due to its chemical composition, LNG produces less of all three types of harmful substances that are often associated with shipping.

LNG does not produce any SOx – for this reason LNG is very often referred to as the ideal solution for the sulfur cap of 2020. Since LNG is mostly methane that contains less carbon and nitrogen than petroleum fuels, it produces more than 25% lower CO2 emissions and 90% lower NOx emissions (Amir, Paul, & Walter, 2018).

It may seem that LNG offers many benefits, especially in the environmental field, and does not have any disadvantages. Unfortunately, this is not the case and there are some issues that need attention.

For example, there are studies showing methane slippage when operating LNG engines at lower power. At the same time, these studies have shown significant reductions in NOx and SOx emissions compared to other petroleum fuels, but overall hydrocarbon emissions were higher than for petroleum fuels – 85% of the exhaust fumes were found to be unburned methane. This phenomenon is known as methane slip, and in the studies conducted, its amount was about 7 grams per kilogram of burned LNG (at high engine power demand) and between 23 and 36 grams per
kilogram of burned LNG (at low power required). Thus, slower combustion at lower temperatures seems to cause a higher release of unburned methane into the atmosphere. However, a seemingly small amount is a very important problem, as methane has a 28 times greater global warming potential than CO2. The total amount of particulate emissions in LNG combustion was smaller than in the MGO, but very small particles predominate in LNG emissions, which are much less common in MGO emissions (Corkhill, 2018).

One of the environmental benefits connected with LNG is that it evaporates in case it should escape the tank. While a leak of MGO or HFO would mean an ecological disaster, the cryogenic temperatures at which LNG is stored in the tank will cause rapid evaporation. On the other hand, these low temperatures and low flash point could result in much greater problems – IGF Maritime Regulations define a range of risks as well as safeguards to address them (Maritime Safety Committee, 2015).
3 A case study - sustainability and profitability of operating LNG powered vessels

In this part of this thesis, differences in initial investment costs between MGO, HFO and LNG powered vessels will be enumerated; the running costs of a 10,000 TEU vessel on various container ship routes in both speed modes (normal speed and slow steaming) compared, yearly fuel costs differentials calculated, payback periods for scrubber systems and LNG systems and their Internal Rates of Return estimated.

3.1 Analysis of current situation

In this chapter, the current situation in respect to fuel prices, ship newbuilding prices, global shipping fleet and shipping routes will be described.

3.1.1 Fuel prices by region

Having selected the set of fuels – HFO, MGO and LNG, it is necessary to find out respective fuel prices for each region. The vast majority of larger cargo ships spend their lives going back and forth between continents, calling in various ports on their way. Knowing the prices of fuel do differ (even though only slightly in some instances), this difference has to be taken into account considering the very large amounts of fuel large ships consume on their journeys. In the graphs below, the mean fuel prices for each region are summarized and these will be used in quantitative research in next parts of this thesis.

To represent the fuel choices for scrubber equipped ships running high sulfur fuels, IFO380 and IFO180 were selected – both of these fuels readily available at virtually any cargo port around the world. As is apparent from the graphs, both of these fuels are cheapest in Europe and most expensive in India. Other locations show price differences lower than ±5%.
Figure 6 Prices of IFO380

Figure 7 Prices of IFO180
As already mentioned, with the 2020 IMO sulfur cap regulations closing in, it will be mandatory to run low or ultra-low sulfur fuels for vessels not equipped with scrubber systems. For these ships with conventional engines, the clear choice is MGO or Marine Gas Oil, a fuel already very similar to ordinary diesel. Europe, again, is the cheapest area and India the most expensive one. The price variance of other locations is slightly higher than with IFO, floating around ±10%.

LNG, alternative fuel of choice for this research, is cheapest in North America and most expensive in Asia. Price variance of other locations lies around ±10%. LNG, unlike IFO and MGO, is not sold and measured by the ton, but rather by MMBtu – it stands for one million British thermal units (BTU), which is a traditionally used unit of heat. For the purpose of easy and objective comparison of running costs between conventional fuels and LNG, a fuel equivalent factor was established – as described in chapter 3.1.2.
For summarization, a graph of average fuel prices has been compiled below. In case of LNG, a fuel equivalent factor (described in 3.1.2) was used to accommodate for direct comparison to marine oils.

**Figure 9 Prices of LNG**

**Figure 10 Average fuel prices**
3.1.2 Calorific values of fuels and fuel equivalent factors

Since available data about vessel fuel consumption is expressed in tons of HFO per day and the purpose of the research is to compare costs of different fuel types, it is necessary to establish a “fuel equivalent factor” to estimate the difference in amount of fuel used to generate the same amount of energy.

The mean fuel equivalent factor for 1 m³ of LNG is 0,554 ton of HFO (Marine Service GmbH, 2005). Since cubic meters are not used a common unit for amount of LNG and the industry standard for quantification is MMBtu (millions of British thermal units), it is needed to modify the calculation to purposes of this thesis. Knowing the calorific values of both LNG and HFO and specific density of LNG it was possible to establish a fuel equivalent factor of: 1 ton HFO = 43,33 MMBtu LNG.

To make the calculation of fuel costs for MGO powered vessels possible, it was needed to go through a similar process. Based on calorific values of both MGO and HFO, there was established a fuel equivalent factor of: 1 ton HFO = 0,91 ton MGO.

Aforementioned factor constants will be used in calculations of fuel costs for specific routes and evaluations of profitability of each fuel type.

3.1.3 Shipping routes for calculation of fuel costs

For the purpose of this thesis, it was chosen to analyse the fuel costs in container shipping, as it is one of the most important cargo shipping methods, after bulkers and tankers. Also, container ships have the most direct connection with end customers and consumers, therefore any changes happening have a potential to have a direct impact which will be transferred to individual consumers.

Container ships usually sail on a given route between two ports, sometimes calling in more ports on the way (to pick up more cargo), however this is not very frequent with large vessels, because they are hard to maneuver. For the purpose of this research, the most common trade routes of container ships were reviewed and in combination with available fuel prices data, several of them were selected for running costs calculation.

Following trade routes will be used in this research:

a) Asia to North America
b) Asia to Europe
c) Asia to South America
d) China to India
3.1.4 Global shipping fleet in 2018

To put the selection of container ships for this research into perspective within the global shipping fleet, the following table was compiled. According to UNCTAD the global shipping fleet, in terms of total DWT is comprised of 43% bulk carriers, 29% oil tankers, 13% container ships, 11% other vessels and 4% general cargo. While the percentage share of total DWT of container ships may seem small – especially in comparison with bulk carriers – container shipping industry has a direct impact and connection with end-customers and consumers. Bulk carriers usually ship f.e. metal ore, which goes through number of processing steps and many companies until it makes its way to consumers in form of finished goods, which will – most probably – be delivered aboard a container ship (UNCTAD, 2019).

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of vessels</th>
<th>DWT (thousands)</th>
<th>% of total DWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Tankers</td>
<td>10 420</td>
<td>561 079</td>
<td>29</td>
</tr>
<tr>
<td>Bulk Carriers</td>
<td>11 125</td>
<td>818 613</td>
<td>43</td>
</tr>
<tr>
<td>General Cargo</td>
<td>19 613</td>
<td>74 459</td>
<td>4</td>
</tr>
<tr>
<td>Container Ships</td>
<td>5 164</td>
<td>252 825</td>
<td>13</td>
</tr>
<tr>
<td>Other</td>
<td>47 847</td>
<td>217 028</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>94 169</td>
<td>1 924 004</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2 Global shipping fleet in 2018 (UNCTAD, 2019)
3.1.5 Costs of acquiring and running vessels powered by MGO

MGO, unlike HFO does not have to be heated during use and storage and also contains low amounts of sulfur – therefore is it a fit option of a conventional fuel compliant with the 2020 sulfur cap. Vessels powered by MGO burning engines do not carry any additional costs with initial expenditure nor during their operation – therefore MGO powered vessels will be used as a baseline value for both initial investment and running costs in the quantitative research of this thesis.

The only real downside of using MGO as a fuel is its higher price per ton in comparison to HFO or IFO and LNG. It has higher calorific value per ton than HFO or IFO, does not need any special fuel tanks like LNG does and is readily available in any cargo port in the world.

Initial investment costs for various cargo vessel types powered by MGO are laid out in graph below, ranging from VLCC (Very Large Crude Carrier) over bulk carriers to multiple sizes of container ships. Average cost for the 10.000 TEU container ship, which was selected to be used in this research, is 93 million USD. However, it must be noted, that newbuilding ship prices are very seasonal and can vary in in tenths of percent just from month to month.
3.1.6 Costs of running and acquiring vessels powered by HFO with scrubber system

Unlike MGO, HFO and IFO have high sulfur content and it will not be possible to operate vessels powered with these types of fuels without any type of scrubber or exhaust gas aftertreatment system after the 2020 sulfur cap comes into effect. Installing a scrubber system comes with elevated initial investment and also higher operational costs, but these are, unlike the higher investment, reasonably low and can be, to avoid overburdening the reader, ignored for the purpose of this thesis.

As already mentioned, there are more types of scrubber systems – open, closed and hybrid – each with their own respective benefits and drawbacks. Since container ships will operate during their lifetime in scrubber regulated and unregulated waters (some ports forbid to operate open loop scrubbers to avoid contaminating the water), a hybrid scrubber will be considered as the ideal choice. Also being the most expensive out of aforementioned three types, it will simulate the “worst case” scenario with additional initial investment. As can be seen in the graph below, the cost for the same 10.000 TEU container ship with a hybrid scrubber system is 120,9 million USD – approximately 27 million USD more than an MGO powered ship.
3.1.7 Costs of running and acquiring vessels powered by LNG

In the context of expected further tightening of emission standards (IMO Sulfur cap and others) and, as already described, LNG seems to have the highest chance of being used as an alternative fuel of future for all types of ships. The most commonly noted advantage of LNG lies in the environmental context, because it produces no Sox emissions, almost 95% less NOx emissions, more than 98% lower amounts of particulates and approximately 25% lower CO2 emissions than conventional fossil fuels which are being used today as main source of power for all vessels (Amir, Paul, & Walter, 2018).

Just like both types of fossil fuels used in this research, MGO and HFO, LNG brings along some disadvantages. One of the most notable obstacles for LNG to dominate the market as new fuel for the global shipping fleet is (and has been) the significantly worse infrastructure of bunkering stations. While it is necessary to mention this issue, it is expected to be solved very rapidly with most large ports either already building or planning to build bunkering stations for LNG (European Commission, 2013). The spread of information about aforementioned initiatives has caused an increase in demand for LNG powered vessels, both in the newbuilding industry and conversion of existing ships.

![Initial investment of HFO powered ships w. scrubber (USD mil.)](image-url)
As stated in the first paragraph, LNG has some definite advantages over HFO, IFO, MGO and generally over any type of conventional fossil fuel. But in addition to the lacking infrastructure, LNG (as the name implies – Liquified Natural Gas) must be stored in its liquid state in order to be usable as ship fuel and this is possible only in temperatures below -162°C. While not being apparent at the first glance, the cryogenic temperatures and other chemical and mechanical properties of LNG facilitate the need for special fuel tanks, which take up more space than ordinary steel tanks for liquid conventional fossil fuels (about two to three times). And these special tanks are one of the major items in the higher additional cost of LNG powered vessels. In comparison to fossil fuels, LNG powered ships are, based on empirical data, 20-30% more expensive, which can be identified as one of the root causes of lower demand for these vessels. Other factors demand influencing factors are skepticism about the viability of LNG as alternative fuel, uncertain future development of fuel prices, safety issues, unproven reliability of LNG powered engines and prominently lack of empirical data connected with economic sustainability of LNG powered ships (DNV GL, 2015). The above identified factors play a major role in the slow development of demand for such vessels.

In the graph below the initial investments for different types of vessels were summarized. Tankers, bulkers and container ships (of same types and sizes as used with MGO and HFO) were, again, included. As already mentioned, empirical data shows an average price increase of approx. 25% for LNG powered vessel over its MGO powered counterpart. The values shown in the graph were calculated with the aforementioned assumption.

![Initial investment of LNG powered ships (USD mil.)](image)

Figure 15 Initial investment of LNG powered ships
When discussing fuel prices and comparing fuel prices, a special approach and care needs to be taken for LNG. On the account of undeveloped LNG bunkering infrastructure, prices differ greatly across the globe. While it is possible to fill the ship's tank with LNG for less than 4 USD per MMBtu, the shipping company can easily pay more than 9 USD or even 12 USD per MMBtu. Estimated LNG landed prices as of December 2018 can be seen in the map below.

![World LNG Estimated Landed Prices: Dec-18](image)

Figure 16 World LNG Estimated Landed price 12/2018 (Global LNG Hub, 2018)

### 3.2 Profitability of LNG powered vessels in comparison with MGO and HFO with scrubber system

In order to assess the profitability of LNG powered vessels it is needed to calculate both the initial differences in ship prices and differences in operational costs (connected with fuel consumption). In the first part of this chapter, the differences between initial investments with various fuel types will be evaluated and the benefits of each fuel summed up. In the second part, the operational costs for each fuel type will be calculated with estimated vessel lifetime of 30 years. The last part of this chapter will be concerned with comparison of gathered data – for this to happen it is needed to set up a baseline in form of an MGO powered vessel.
3.2.1 Initial investment comparison

To compare the newbuilding ship prices for each fuel type, it is necessary to first acquire price data for normal vessels (in this case MGO powered), which do not have any additional equipment on board and are fairly simple as far as fuel and propulsion systems go and can be therefore considered a baseline for this research. The table below encompasses various ship types, which represent the majority of global shipping fleet – oil tankers, bulk carriers and container ships. The prices for container ships are substantially higher than for bulkers and tankers, with container ships costing more than twice as much than a bulker or tanker of the same DWT.

<table>
<thead>
<tr>
<th>Ship type</th>
<th>Size</th>
<th>Price MGO</th>
<th>Price HFO w. scrubber</th>
<th>Price LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLCC</td>
<td>320.000 DWT</td>
<td>80,5</td>
<td>87,5</td>
<td>100,6</td>
</tr>
<tr>
<td>Capesize</td>
<td>180.000 DWT</td>
<td>42,5</td>
<td>48,5</td>
<td>53,1</td>
</tr>
<tr>
<td>Suezmax</td>
<td>160.000 DWT</td>
<td>53</td>
<td>59</td>
<td>66,3</td>
</tr>
<tr>
<td>Aframax</td>
<td>120.000 DWT</td>
<td>43</td>
<td>48</td>
<td>53,8</td>
</tr>
<tr>
<td>Panamax</td>
<td>80.000 DWT</td>
<td>24,5</td>
<td>28,5</td>
<td>30,6</td>
</tr>
<tr>
<td>Handymax</td>
<td>65.000 DWT</td>
<td>23,5</td>
<td>26,5</td>
<td>29,4</td>
</tr>
<tr>
<td>MR</td>
<td>50.000 DWT</td>
<td>33,5</td>
<td>36,5</td>
<td>41,9</td>
</tr>
<tr>
<td>Container 18.000 TEU</td>
<td>210.000 DWT</td>
<td>144,5</td>
<td>151,5</td>
<td>180,6</td>
</tr>
<tr>
<td>Container 13.000 TEU</td>
<td>120.000 DWT</td>
<td>109</td>
<td>115</td>
<td>136,3</td>
</tr>
<tr>
<td>Container 10.000 TEU</td>
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<td>93</td>
<td>99</td>
<td>116,3</td>
</tr>
<tr>
<td>Container 8.800 TEU</td>
<td>100.000 DWT</td>
<td>83</td>
<td>88</td>
<td>103,8</td>
</tr>
<tr>
<td>Container 6.600 TEU</td>
<td>80.000 DWT</td>
<td>60</td>
<td>64</td>
<td>75</td>
</tr>
<tr>
<td>Container 4.800 TEU</td>
<td>60.000 DWT</td>
<td>43,8</td>
<td>47,8</td>
<td>54,8</td>
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<td>30,8</td>
<td>34,8</td>
</tr>
<tr>
<td>Container 1.700 TEU</td>
<td>30.000 DWT</td>
<td>22,3</td>
<td>24,3</td>
<td>27,9</td>
</tr>
</tbody>
</table>

Table 3 Newbuilding ship prices (USD million)

Newbuilding ship prices for vessels equipped with scrubber systems are increased proportionately with respect to the installed engine power and are not directly related with the ship size, since vessel operators can select different engines for a vessel of the same class or size. To make this comparison possible and estimate the additional costs for scrubber systems, an engine for each ship size mentioned in the table above was selected based on information about engines widely used for the respective ship size or type. Using the data published by MAN Diesel & Turbo in their papers on propulsion trends for bulkers and container vessels, it was possible
to pick suitable engines, which satisfy the travel speed requirements of each ship in accordance with the function of Relative propulsion power – (MAN Diesel & Turbo, 2014) and (MAN Diesel & Turbo, 2013). Since container ships are designed to travel faster than bulkers, they need more powerful engines – which explains the difference in additional costs of scrubber systems for bulkers and container ships of the same DWT.

The prices of LNG powered vessels in the table above are directly proportional to their MGO powered counterparts. Since the whole industry is fairly new, there is no available data about newbuilding prices for each vessel size or type. But empirical evidence, as suggested by DNV GL, states, that the price increase of an LNG powered ship lies between 20 to 30 percent (DNV GL, 2015). This gives an average price increase of 25 percent and it was used as a price increase coefficient in calculating newbuilding prices for LNG powered vessels in the table above. Author of this thesis however notes, that these figures could change over time – ship newbuilding industry is very seasonal and prices can vary greatly and market for LNG propulsion systems will most certainly see increased competition in the near future – therefore this research captures the whole ship market in a certain point in time and should not be used as an absolute indicator.

![Initial investment comparison (USD mil.)](image-url)
Expressing the initial investments for various ship sizes graphically, a similar trend for both general types of vessels can be identified. Tankers and bulkers (on the left side of the graph, ranging from VLCC to MR) are always cheapest with MGO engines and most expensive with LNG engines, HFO with scrubber systems holding the middle ground between these two extremes. On the other hand, for container ships is the HFO with scrubber system always the most expensive option, with MGO being again the cheapest and LNG now in-between. This is caused, as already discussed above, by differences in installed engine power for tankers/bulkers and container ships of the same DWT – container ships are designed to cruise faster, therefore needing more engine power and directly related more expensive scrubber systems.

### 3.2.2 Selection of a vessel for fuel cost calculation

The vessel used for the purpose of fuel cost calculation shall be a 10,000 TEU container ship. Its fuel consumption function is illustrated in the figure below.

![Graph of fuel consumption by container ship size and speed](image-url)

*Figure 18 Fuel Consumption by container ship size and speed (The Geography of Transport Systems, 2017)*
3.2.3 Yearly fuel costs comparison

The next important step in this research is comparing the running costs for various fuels – MGO, IFO (for ships with scrubbers) and LNG. Since cargo ships use the world’s largest engines, it is no wonder their fuel requirements for a day on the sea are extraordinary. Based on aforementioned fuel prices for various regions, selected container ship routes, fuel equivalent factors and other variables, yearly fuel costs for a 10,000 TEU container ship operating in two speed regimes – a) slow steaming and b) normal speed – were calculated.

Each route was calculated with an assumption that the container ships spends 250 days a year cruising at sea under engine power. The rest of the days are thought to be spent in port while loading or unloading cargo and during maintenance in wet or dry dock. To keep focus on the differences in fuel prices in various locations during this research and keep it realistic, both ways of each trip were included in the calculation – e.g. Asia to North America (using fuel from Asia) and North America to Asia (using fuel from North America).

3.2.3.1 Asia - North America route while slow steaming

In this case, the 10,000 TEU container ship is operating on a route between Asia and North America. Using the mean fuel prices of Asia for the way to North America and vice versa, with assumed 250 days at sea under engine power and with fuel consumption of 125 tons of fuel per day, the fuel costs on this route are following:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$13,526,042</td>
<td>$14,361,979</td>
<td>$18,211,136</td>
<td>$11,521,681</td>
</tr>
</tbody>
</table>

Table 4 Fuel costs Asia - North America route with slow steaming

Expressing the results graphically, it can be seen that on Asia – North America route is LNG the cheapest fuel option to run and MGO the most expensive (by almost 7 million USD a year). Both qualities of IFO – IFO380 and IFO180 – are slightly more expensive than LNG (by 2 and 3 million USD respectively).
3.2.3.2 Asia - North America with normal speed

In this calculation, the container ship is travelling on the same route with identical time schedule (250 days at sea), only difference being the ship speed. In the previous example, the assumed ship speed was 18 knots, which qualifies as slow steaming. For this instance, the speed is set to 24 knots, which is also the designed speed for most container ships. Fuel consumption for this vessel size and speed is 325 tons per day – an increase of 200 tons or 260% from 125 tons while slow steaming.

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 24 346 875</td>
<td>$ 25 851 563</td>
<td>$ 32 780 045</td>
<td>$ 20 739 025</td>
</tr>
</tbody>
</table>

Table 5 Fuel costs Asia - North America route with normal speed

Looking at the graph below, the same pattern can be observed for this route even with higher fuel consumption – LNG is the cheapest option, MGO most expensive and both IFOs lie in-between.
3.2.3.3 Asia - Europe while slow steaming

For this example, the route has been changed from Asia – North America to Asia – Europe. With the same principle for fuel price calculation – Asian prices for the way to Europe, European prices for the way back to Asia and identical time spent at se, the total yearly costs can be seen in the table below:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$25 240 385</td>
<td>$26 983 173</td>
<td>$32 631 622</td>
<td>$22 672 460</td>
</tr>
</tbody>
</table>

Table 6 Fuel costs Asia - Europe route with slow steaming

Again, expressing the numbers graphically, LNG takes the place of cheapest fuel option and MGO of the most expensive with IFOs in the middle. There is an impact of higher European LNG prices and lower IFO and MGO prices on the total yearly costs and as well on the differences between total costs of various fuel options – percentual differentials are lower than on Asia – North America route (graph in attachment).
3.2.3.4 Asia - Europe with normal speed

Knowing the fuel costs increase caused by the higher European fuel prices from the previous example, a dramatic increase of these costs can be expected with higher, normal, speed – which is 24 knots for the ship selected for this case study. Costs are compiled in the table below.

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 49 875 000</td>
<td>$ 53 318 750</td>
<td>$ 64 480 086</td>
<td>$ 44 800 781</td>
</tr>
</tbody>
</table>

Table 7 Fuel costs Asia - Europe route with normal speed

The graph follows the same trends as this route with slow steaming. LNG is the cheapest fuel option, being more than 5 million USD cheaper a year than its closest competitor, which is IFO380. MGO is the most expensive fuel, creating 20 million USD more of operational expenditure a year (graph in attachment).

3.2.3.5 Asia - South America while slow steaming

Using next popular container shipping route, Asia to South America, with the ship spending 250 days at sea with slow steaming speed of 18 knots, the calculated yearly fuel costs are summed up below:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 22 555 288</td>
<td>$ 23 824 519</td>
<td>$ 31 713 832</td>
<td>$ 20 795 819</td>
</tr>
</tbody>
</table>

Table 8 Fuel costs Asia - South America route with slow steaming

Having established the fact, that LNG in South America is more expensive than in North America or Europe and the price of IFO’s is comparable, smaller difference is expected between total costs of operating a vessel powered by LNG and IFO. This is proven to be true by the graph, but LNG takes the place of cheapest fuel option, but only by 1 million USD in comparison to IFO380. MGO is the most expensive option with very noticeable additional costs, caused by its price in the South America – more expensive than in both Europe and North America (graph in attachment).
3.2.3.6 Asia - South America with normal speed

The same 10,000 TEU container ships frequenting the same route for 250 days a year with average speed of 24 knots generates following operational costs from fuel consumption:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 42,650,000</td>
<td>$ 45,050,000</td>
<td>$ 59,967,974</td>
<td>$ 39,323,004</td>
</tr>
</tbody>
</table>

Table 9 Fuel costs Asia - South America route with normal speed

As illustrated in the graph, the total costs for operating LNG powered vessels and IFO powered ones are still very close, even with the increased fuel consumption of normal speed mode, showing a difference of only 2.5 million USD between LNG and IFO380. MGO is the most expensive and due to its high price, the additional expenditure of MGO vessel is almost 17 million USD when compared to LNG (graph in attachment).

3.2.3.7 China - India while slow steaming

Since India has the highest fossil fuel prices, one shorter route was included in this research and that is from China to India, with the intent to uncover possible differences in best fuel options caused by the increase in prices of various fuels.

With ship size held constant and slow steaming speed of 18 knots, the yearly fuel costs are following:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 12,414,663</td>
<td>$ 12,983,173</td>
<td>$ 17,470,300</td>
<td>$ 10,443,741</td>
</tr>
</tbody>
</table>

Table 10 Fuel costs China to India route with slow steaming

Expressing the prices graphically for easier comparison, it can be identified that LNG is once again the cheapest fuel to operate, with MGO being the most expensive – by more than 8 million USD over LNG. IFO180 and IFO380 have negligible differences between them in this case and stand the middle ground being approximately 3 million USD more expensive than LNG (graph in attachment).
3.2.3.8 China - India with normal speed

Using the same short China – India route for the ship, in this instance with normal designed speed of 24 knots, the yearly fuel costs rise to these values:

<table>
<thead>
<tr>
<th>Fuel cost IFO380</th>
<th>Fuel cost IFO180</th>
<th>Fuel cost MGO</th>
<th>Fuel cost LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$23,475,000</td>
<td>$24,550,000</td>
<td>$33,034,749</td>
<td>$19,748,164</td>
</tr>
</tbody>
</table>

Table 11 Fuel costs China to India route with normal speed

Seeing the table summarized in the graph, the same pattern is observed as noticed with slow steaming, but with the increased fuel consumption caused by higher travel speed, the price differences are much more severe – with MGO being more than 20 million USD more expensive to operate and IFOs approximately 7 million USD more expensive (graph in attachment).

3.3 Yearly fuel cost difference (%)

In the previous chapter several container ship routes were selected to be used for the purpose of this research and the yearly fuel costs of a 10,000 TEU container ship operating these routes were calculated and compared.

In this chapter, the percentual differentials of various fuel types with respective mean prices for the same routes will be expressed. MGO will be used as a baseline value with 100% of the cost.

Price differentials for all fuel types and routes have been summarized in the table below and each route will be described separately with graphical explanation. Based on the data drawn up in the table, it can be said that the cost of operating and LNG powered vessel is generally between 60%-69% of the cost of MGO powered one. IFO powered ships equipped with scrubbers cost 71%-83%.

<table>
<thead>
<tr>
<th></th>
<th>IFO380</th>
<th>IFO180</th>
<th>MGO</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia - North America</td>
<td>74%</td>
<td>79%</td>
<td>100%</td>
<td>63%</td>
</tr>
<tr>
<td>Asia - Europe</td>
<td>77%</td>
<td>83%</td>
<td>100%</td>
<td>69%</td>
</tr>
<tr>
<td>Asia - South America</td>
<td>71%</td>
<td>75%</td>
<td>100%</td>
<td>66%</td>
</tr>
<tr>
<td>China - India</td>
<td>71%</td>
<td>74%</td>
<td>100%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Table 12 Price differentials of various fuel types for selected container ship routes
Looking at the graph of fuel price differentials for the Asia – North America route, the established pattern of LNG being the cheapest option repeats itself, in this case amounting for 63% of the cost of MGO. IFO380 amounts for 74% and IFO180 for 79% of the fuel costs of MGO.

This confirms the assumption that LNG is economically profitable on Asia – North America route, with the judgement being based exclusively on fuel costs. IFO powered ships with scrubbers have also the potential to be more profitable than MGO powered ones, but not as profitable as LNG powered vessels.

The Asia – Europe route tells a similar story, despite the differences in fuel prices in Europe. MGO, the baseline fuel, is the most expensive and LNG the cheapest, with its cost amounting to 69% of MGO. IFO380 and IFO180 amount for 77% and 83% respectively (graph in attachment).

LNG is therefore the most profitable fuel option for Asia – Europe route, based on the fuel costs itself. IFO powered vessels with scrubbers are the second most profitable option.
The route from Asia to South America shows effects of more expensive LNG in South America and fairly low prices of IFO – as a consequence, there is only a 5% difference between price differentials of LNG and IFO380 for this route (graph in attachment).

Despite this fact, LNG is still the most profitable option with both IFOs coming in close second. MGO is, again, the least profitable variant based on fuel costs alone.

The shortest of selected routes, China – India, is putting up with the highest fuel prices out of all above mentioned. With very expensive IFO180, in comparison to IFO380, the lowest spread of price differential between these two IFOs is observed – only 3%. Caused mainly by very expensive MGO in India, the graph shows the highest spread of price differential between MGO and LNG – 40% (graph in attachment).

LNG is the most profitable option for China – India route, amounting to 60% of MGO costs, with IFOs being the second most profitable fuel choice – 71% and 74% for IFO380 and IFO180 respectively.

### 3.4 Payback period

In the previous chapter, the fuel cost differential for various fuels on selected routes for this research was described. While it was established that on every route is LNG the cheapest or most profitable option, both the price differential and fuel cost calculation take into account the fuel costs itself, without any respect to the difference in initial investment. To be able to objectively say, which option is the most profitable for shipping companies, it is needed to reflect the additional capital expenditure for scrubber system or LNG powered vessels in my research.

In this chapter the payback period for the initial investment will be enumerated. During the literature review, the height of additional capital expenditure for scrubber systems and LNG powered vessels was established. Using these amounts as an investment and the generated cashflows from fuel cost savings, it is possible to calculate payback periods for each fuel type. As already illustrated both by the yearly fuel cost calculation and fuel price differential, the ship operating on different trading routes will be met with different fuel prices. While these variations may not seem severe when viewed as a price for single unit of fuel, they amount to millions of dollars in savings or expenditure per year – therefore the payback period for each route will be calculated and described separately. Additionally, since there have are considered two speed modes of container ship operation (slow steaming and normal speed) with largely varying fuel consumption, payback periods for both speed modes for each route were also calculated.
Looking at the graph below, it is possible to identify a pattern – the higher fuel consumption at higher speeds creates larger savings from cheaper fuels, which shortens the payback period dramatically. In case of IFOs, the difference in payback period between them is directly correlated with the fuel price itself – IFO380 is a little cheaper, therefore has the second lowest payback period. The clear winner on Asia – North America route is LNG with payback periods of 31 or 12 months for slow steaming or normal speed respectively. The longest payback period is for scrubber system equipped ship running on IFO180 – 59 and 23 months for slow steaming and normal speed.

![Figure 22 Asia - North America route payback period](image)

The route from Asia to Europe follows similar trend, with LNG powered vessels having the shortest payback period of 34 and 13 months for slow steaming and normal speed. IFO380 is again second with 49 and 19 months, the more expensive IFO180 having a 5 months longer payback period in slow steaming speed mode takes the last place.
Shifting the attention to route from Asia to South America and analysing the graph below, the trend remains similar – despite the variance of price differentials. The payback periods for LNG and IFO380 in normal speed mode come fairly close with LNG having only 5 months shorter payback period than IFO380. LNG has again the shortest payback period of 36 and 14 months for slow steaming and normal speed, with IFO380 coming second as mentioned above and IFO180 being last with 7 months longer payback period for slow steaming mode.
Coming to the shortest of selected routes, from China to India, the graph shows very long payback periods for both IFOs, which are caused by very high prices of these fuels in India. Uninfluenced by this, LNG comes out on top as the best option with shortest payback period of 36 and 14 months for slow steaming and normal speed, followed by IFO380 with 63 and 24 months. The worst option is IFO180, with 72 months payback period in slow steaming mode.

Figure 25 China - India route payback period

Average values of payback periods for each fuel are summarized and graphically illustrated below. The identified pattern present on all routes repeats here without any doubt, LNG is the best option in terms of payback period with 34 and 13 months for slow steaming and normal speed respectively. IFO380 is again second best with 53 and 21 months. Worst option is IFO180 with longest payback period of 61 and 23 months.

To summarize – LNG powered ships offer on average the shortest payback period on the initial additional capital expenditure in both speed modes.
In the previous chapter the payback periods of vessels equipped with scrubber system running either IFO380 or IFO180 and LNG powered ships were evaluated on selected container shipping routes. To formulate a general conclusion, an arithmetical average of acquired values was used. In order to calculate the payback period, it was necessary to establish the amount of yearly savings connected with respective fuel type and use this amount as a positive cashflow. Knowing the amounts of savings, it is possible to enumerate the Internal Rate of Return for the variety of fuel types used in this research.

Internal Rate of Return is a metric, which is widely used to evaluate the profitability and attractiveness of a potential investment. The internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV does (Hayes, 2019).

Generally speaking, the higher IRR of an investment opportunity, the better. Summarized in the table below are all vital information, less the breakdown of yearly cashflows. IRR was calculated for both speed modes, since the difference in fuel consumption creates variations in yearly cashflows.
The calculation of IRR for the purpose of this research has following assumptions and limitations:

- Investment = additional capital expenditure
- Length = lifetime of ship (considered to be 30 years)
- Inflation rate = 2%
- No clear forecasts of fuel prices for coming years (current prices used and corrected for inflation each year)

<table>
<thead>
<tr>
<th></th>
<th>IFO380</th>
<th>IFO180</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>$27,880,000</td>
<td>$27,880,000</td>
<td>$23,250,000</td>
</tr>
<tr>
<td>Length (years)</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Yearly CF slow steaming</td>
<td>$6,334,635.42</td>
<td>$5,543,619.79</td>
<td>$8,161,874.78</td>
</tr>
<tr>
<td>Yearly CF normal speed</td>
<td>$16,470,052.08</td>
<td>$14,413,411.46</td>
<td>$21,220,874.43</td>
</tr>
<tr>
<td>IRR slow steaming</td>
<td>25%</td>
<td>22%</td>
<td>37%</td>
</tr>
<tr>
<td>IRR normal speed</td>
<td>61%</td>
<td>54%</td>
<td>93%</td>
</tr>
</tbody>
</table>

Table 13 Internal Rate of Return for various fuel types

Looking at the IRR while assuming slow steaming speed mode during the lifetime of the ship, it can be seen that LNG has the highest IRR with 37%, IFO380 second highest with 25% and IFO180 the lowest with 22%. Knowing the decision-making principle connected with IRR calculations – the higher the better – LNG is the clear winner here. Depending on the WACC of the respective shipping company, selecting an LNG powered vessel should be profitable and the investment project should generate a growth of 37%.

Calculating the IRR for normal speed mode during the lifetime of the ship, the pattern remains the same with different IRRs. LNG is again the best option with very high IRR of 93%, IFO380 is second best with 61% and IFO180 worst with 54%. While both IFOs are still viable and profitable options, the IRR of LNG is highest by more than 32% than of IFO380. With IRR of LNG powered vessel in normal speed mode being as high as 93%, it can be most certainly said that such an investment project will be profitable.
3.6  Sustainability of LNG powered vessels in comparison with MGO and HFO with scrubber system

The sustainability of LNG powered vessels could be compared in two scopes:

a) Fuel reserves
b) Emissions and environmental impact

3.6.1  Fuel reserves

Beginning with the fuel reserves, both MGO and HFO/IFO are manufactured from crude oil. Taking a look at world crude oil reserves according to OPEC, there are approximately 1 482 billion of barrels in proven world reserves, as illustrated in the graph below (OPEC, 2017).

According to data, current world crude production is approximately 80 million barrels a day (YCharts, 2019), which means the proven world crude reserves as of 2017 would be exhausted in 51 years from now at this rate of production.

LNG, as the name suggests, is made from natural gas by liquefying it. According to OPEC, the proven world reserves of natural gas are 200 000 billion standard cubic meters. The current rate of world natural gas production is 3 740 billion cubic meters a year, which means the current proven reserves will last for 54 years at the same rate of production. For natural gas, like for crude oil, exist more possible
technically recoverable reserves. These recoverable reserves amount according to IEA, BP and Reuters to more than 550,000 billion standard cubic meters, which – at current rate of production – would be sufficient for 147 years (Siluria Technologies, 2011).

To summarize – when we take all possible recoverable natural gas reserves into account, LNG can be considered as a sustainable source of power for the next 100 years or more, depending on the growth of production and consumption of natural gas.

3.6.2 Emissions and environmental impact

As already explored in the Literature review, LNG has lower emissions of CO₂, NOₓ and SOₓ, as well as particulate matter. This change would be very beneficial for the environment, since the global shipping fleet is responsible for 18-30% of NOₓ, 9% of SOₓ and 3.5-4% of CO₂. With LNG, NOₓ and SOₓ emission could be virtually eliminated and CO₂ emission at least lowered by 20-25%.

However, LNG does come with one issue connected to the exhaust gas pollution – and that is so called methane slip. During the gas exchange phase of Otto engine cycle, there is a possibility for the gas to escape the combustion chamber. While this could be considered negligible, because greenhouse gases are composed of 85% CO₂ and only 9% methane, the same amount of methane has 25 times more adverse impact on climate change than CO₂. Nevertheless, Otto engines underwent a significant development in recent years and the future promises catalysts which would be able to completely remove Total Hydrocarbon Emissions from the exhaust gases.
3.7 Questionnaire research – View of LNG powered vessels

In previous parts of this thesis, the focus was laid on the quantitative research with calculation of fuel costs and potential savings connected with various fuel options, payback periods and internal rates of return. But as already hinted by the title and goal of this thesis along with literature review, the economical side of this case study is not to be evaluated alone, but rather in tight connection with CSR strategy of shipping companies.

In today’s age, CSR strategies and their perception by customers plays a major role in overall performance of companies, being widely used as a marketing tool in saturated market with fierce competition. During the literature review, it was identified that shipping industry has been (and still is) considered to be a laggard in respect of formulating and implementing CSR or ESG strategies. It surely is interconnected with the fact that customers in heavy industries and similar markets are less sensitive to CSR strategies of various companies on the market than for example consumers in market for cosmetics.

In this chapter, the hypotheses for questionnaire research of companies and customers will be established (five hypotheses for each group), the data gathered and summarized and hypotheses subsequently tested with statistical methods.

3.7.1 Hypotheses for shipping companies

For the purpose of defining the questions used in the questionnaire and subsequent statistical testing, following hypotheses were defined for shipping companies:

- H0: There is no association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.
  - H1: There is an association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.

- H0: The opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are not correlated.
  - H1: The opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are correlated.

- H0: There is no association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.
• H1: There is an association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.

• H0: There is no association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.

  o H1: There is an association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.

• H0: There is no association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.

  o H1: There is an association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.

3.7.2  Hypotheses for customers

For the purpose of defining the questions used in the questionnaire and subsequent statistical testing, following hypotheses were defined for customers. For each null hypothesis there is an alternative hypothesis provided:

• H0: There is no association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company.

  o H1: There is an association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company.

• H0: There is no association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.

  o H1: There is an association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.

• H0: There is no association between the opinion of customers about environmental performance of a shipping company and their opinion about which aspect of CSR is the most important.
3.7.3 View of LNG powered vessels by shipping companies – questionnaire

To acquire knowledge necessary to test the hypotheses, which have been laid down, a questionnaire study consisting of 10 questions was conducted among shipping companies operating cargo and cruise ships.

Research sample:

- 30 largest companies in both shipping sectors
- Phone interviews and/or email
- Response rate of 56.7%
- Total of 17 responses

The first question was aimed at identifying whether the trend of shipping industry being subaverage in respect of CSR strategy implementation still persists or the situation has changed. In this study, 94.1% of respondent companies have formulated and implemented a CSR strategy – so a clear overwhelming majority.

Second question tried to find out the share of companies issuing periodical CSR or ESG reports. While a company can have its CSR strategy implemented, it is possible they do not issue reports about it – which hinders the communication of CSR
strategy goals and their fulfilment between company and customer. I have established, that 70.6% of respondent companies publish periodical CSR or ESG reports. That means some companies, despite having a CSR strategy, still do not issue reports periodically.

![Pie chart showing 70.6% Yes and 29.4% No to the question: Does your company publish CSR or ESG reports?]

**Figure 29 Company questionnaire question 2**

Third question was a panel aimed at identifying the perceived value of company’s CSR strategy in eyes of customers. Respondents had the possibility to evaluate this question on a scale of 1 to 5, with 1 representing “not at all” and 5 “very much”. We can see that the most common answer with 47.1% of respondents was number 4 – therefore it is possible to say, that shipping companies are believe their customers value their CSR strategies a lot.

![Bar chart showing distribution of responses to the question: How much do you think your customers value your CSR strategy?]

**Figure 30 Company questionnaire question 3**

Fourth question tried to identify the significance of the environmental aspect in CSR strategy of respondent companies. Evaluation system was identical to that in question 2, with 1 representing “not at all” and 5 “very much”. Most common
question was number 5 with **47,1%** of respondent companies saying that the environmental aspect is very significant in their CSR strategy.

**Figure 31 Company questionnaire question 4**

The fifth question elaborates on the way the shipping companies view alternative fuels. Believing in success of alternative fuels as a future replacement of fossil fuels is a key variable defining the demand for LNG powered vessels. Based on the outcome of this question, we can say that **94%** of respondents believe in alternative fuels taking the place of fossil fuels in the future, however **53%** of respondents think it will take a long time before this happens.

**Figure 32 Company questionnaire question 5**
Question number 6 is trying to find out the attitude of companies towards the 2020 sulfur cap and the way they will cope with the new legislation. As we can see from the graph below, the most popular option with 41.2% of respondents is retrofitting of scrubber systems. This is a logical and expectable outcome, since virtually any existing ship can be fitted with scrubber. Fairly surprising is the increasing demand for retrofitting of LNG systems, with 29.4% of respondents, however over the past years the technology got more accessible and is especially suitable for conversion of cruise ships, where the ship is quite literally split in half with additional section with LNG tank and other equipment added in the middle. Third most popular option is acquiring new vessels powered with LNG with 17.6%, which together with the percentage of respondents willing to convert their vessels to LNG, hints on the fact, that shipping companies start to explore the alternative fuels and connected economic benefits. The graph shows very low demand for actually using the low sulfur fuels, most probably because of the added running costs, and also very low demand for new ships with scrubbers, possibly due to their longer payback time in comparison to LNG.

![Figure 33 Company questionnaire question 6](image-url)
Seventh question was aimed at the most popular or feasible alternative fuel among the shipping companies. Majority of respondents, 70.6%, voted for LNG as the most feasible alternative fuel among those listed in the questionnaire and visible below in the graph. 12% believe more in biofuel (methanol) and 12% would not pick any fuel from this list.

Figure 34 Company questionnaire question 7

Question 8 explored the awareness of shipping companies about operational expenditures of LNG powered vessels. Vast majority, 82.4%, think these are lower than for MGO powered vessels and only 12% believe these costs are the same as for MGO powered vessel.

Figure 35 Company questionnaire question 8
Question 9 explored the very same thing, but in comparison to HFO/IFO powered ships equipped with scrubbers, rather than with MGO powered ones. The opinions here were fairly varying, with 47% of respondents thinking that LNG has lower operational costs than HFO/IFO and 35% thinking these costs are higher than HFO/IFO. Only 17.6% of respondents believe LNG and HFO/IFO have the same operational expenditures.

Figure 36 Company questionnaire question 9

The last question was aimed at which fuel type are the shipping companies likely to select for their future vessels. 53.3% of respondents chose LNG, 40% of them HFO/IFO with scrubber and only one selected MGO.

Figure 37 Company questionnaire question 10
3.7.4 View of LNG powered vessels by customers of shipping companies – questionnaire

In the chapter 3.6.3, the perspective of shipping companies in respect to alternative fuels in their industry, to their CSR strategies and plans on how to deal with new emission regulations were explored.

In this chapter, the focus will be shifted to customers with a questionnaire consisting of 8 questions.

Research sample:
- Individuals from Europe and USA
- 30-50 years old
- Actively working and using services of shipping companies
- Response rate 60%
- Total of 36 responses

Question one tries to gain deeper understanding on how often do the respondents use the services of shipping companies (as shipping companies in scope of this research are considered only companies which transport goods or people on water). The majority of respondents – 47.2% – use services of shipping companies monthly, 33.3% of respondents use such services rarely (which means once a year or less) and 13.9% consider themselves to be frequent users (more than once a month).

Figure 38 Customer questionnaire question 1
Second question is aimed at finding out the main criteria customers look at while selecting the shipping company whose services they will use. The majority of respondents (51.4%) states that price is the main factor for them, while 31.4% gives the quality of service higher priority. Only 14.3% of respondents have selected the CSR strategy of the shipping company as their main selection criteria.

![Figure 39 Customer questionnaire question 2](image)

Third question shifts the focus to CSR strategies of companies. According to the results of the second question, only a minority of respondents consider CSR strategy as their main criteria while selecting a shipping company. So, I have tried asking a question, whether the respondents would be willing to pay more for the same service, only with better CSR policy. The results were surprisingly positive, with 37.1% saying "Yes" and another 37.1% saying "Maybe", while only 25.7% responded with clear "No".

![Figure 40 Customer questionnaire question 3](image)
Question number four was designed to acquire customers’ opinion about which of CSR aspects should be or is the most important for shipping companies. Respondents could pick between environmental, economic and social performance, or a combination of these. As the most important aspect was identified the environmental one, with social coming in second and economic last.

![Graph: Which aspect of CSR do you consider as most important for shipping companies?](image1)

**Figure 41 Customer questionnaire question 4**

Question five follows up on the environmental part of question four, asking whether the shipping companies care enough for our environment. While the majority, 60%, of respondents think the shipping companies care enough, the other 40% do not share this opinion and do not think positively about shipping companies and their care about environment.

![Pie chart: Do you think shipping companies care enough for the environment?](image2)

**Figure 42 Customer questionnaire question 5**
The sixth question gets insight on the customers opinion about LNG and its sustainability. 57.1% of respondents believe LNG is a sustainable source of power, while 31.4% of them are not sure. Only 11.4% of respondents do not see LNG as sustainable.

![Figure 43 Customer questionnaire question 6](image)

Question 7 was posted in a form of a case study, with the respondents having to choose a company for their vacation ship cruise in Caribbean. They had the option to choose three companies with different prices – the cheapest company running old polluting ships, company with market prices running ships with exhaust aftertreatment or more expensive company with “green” LNG powered ship. The majority of respondents, 54.3%, picked the compromise between price and environmental care in a form of company B with market prices and ships with exhaust aftertreatment. Nevertheless, 42.9% of respondents would be willing to pay more for a cruise on LNG powered ship, which shows that the customers care about the environment when selecting a company for their holiday cruise. Only one respondent would be willing to buy the cheapest cruise on a polluting ship.

![Figure 44 Customer questionnaire question 7](image)
The last, eighth question is similar to the previous one, but aimed at cargo shipping, with the idea that customers may not be so sensitive to the environmental aspect of shipping while they are not in direct contact with the ship – as they are while on a cruise. Again, respondents had the option to choose between companies with different prices – cheaper and more expensive, and with different ships. The cheaper company is running conventional vessels with exhaust aftertreatment, the more expensive one is operating LNG powered ships. Third option for a company with ships without exhaust gas aftertreatment was not given, since these vessels would not be allowed into European ports. As expected, the majority of respondents, 60%, chose the cheaper option. However, quite surprisingly, 40% of them chose the more expensive one, with more focus on the wellbeing of our environment.

Example: While choosing a shipping company to import your products from China to Europe, which of these following companies would you select?

![Customer questionnaire question 8](image)
3.7.5 Hypothesis testing – shipping companies

With the questionnaire data gathered in the previous chapter, it is now possible to continue with hypothesis testing for shipping companies.

- H0: There is no association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.
  - H1: There is an association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.

<table>
<thead>
<tr>
<th>Chi-Square Tests</th>
<th>Value</th>
<th>df</th>
<th>Asymptotic Significance (2-tailed)</th>
<th>Exact Sig. (2-tailed)</th>
<th>Exact Sig. (1-tailed)</th>
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</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
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<tr>
<td>Continuity Correction</td>
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<tr>
<td>Likelihood Ratio</td>
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<td>.107</td>
<td>.294</td>
<td>.294</td>
</tr>
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<td>Fisher’s Exact Test</td>
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<tr>
<td>N of Valid Cases</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 46 Chi-Square test 1

With the p-value of Fisher’s Exact Test being 0.294, which is higher than 0.05, the null hypothesis is not rejected – therefore there is no association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.

- H0: The opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are not correlated.
  - H1: The opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are correlated.
With the p-value of 0.064 being higher than 0.05, the null hypothesis cannot be rejected, therefore the opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are not correlated.

- **H0:** There is no association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.
  - **H1:** There is an association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.

Looking at the Likelihood ratio, the p-value is 0.167, higher than 0.05, which means the null hypothesis holds and there is no association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.
- H0: There is no association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.
  - H1: There is an association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.

**Chi-Square Tests**

<table>
<thead>
<tr>
<th>Value</th>
<th>df</th>
<th>Asymptotic Significance (2-sided)</th>
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</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
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<tr>
<td>Likelihood Ratio</td>
<td>13.464</td>
<td>9</td>
</tr>
</tbody>
</table>

\[a. 15 \text{ cells (93.8\%) have expected counts less than 5. The minimum expected count is } 0.6.\]

Figure 49 Chi-Square test 3

The p-value of Likelihood ratio is 0.143, which is higher than 0.05, therefore the null hypothesis is not rejected and there is no association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.

- H0: There is no association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.
  - H1: There is an association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.

**Chi-Square Tests**

<table>
<thead>
<tr>
<th>Value</th>
<th>df</th>
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<tr>
<td>Pearson Chi-Square</td>
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<tr>
<td>Likelihood Ratio</td>
<td>7.526</td>
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</tbody>
</table>

\[a. 8 \text{ cells (98.9\%) have expected counts less than 5. The minimum expected count is } 18.\]

Figure 50 Chi-Square test 4
The Likelihood ratio has a p-value of 0.111, higher than critical value of 0.05, and for that reason null hypothesis is valid – there is no association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.

### 3.7.6 Hypotheses testing – customers

In this chapter, the testing of hypotheses will be conducted with the data acquired from customer questionnaire.

- H0: There is no association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company.
  
- H1: There is an association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company.

#### Chi-Square Tests

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
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<tr>
<td>Likelihood Ratio</td>
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<td>N of Valid Cases</td>
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</tr>
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</table>

* 17 cells (38.0%) have expected counts less than 5. The minimum expected count is 5.

Figure 51 Chi-Square test 5

#### Symmetric Measures

<table>
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<tr>
<th></th>
<th>Value</th>
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<tr>
<td>Nominal by Nominal</td>
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<tr>
<td></td>
<td>Cramér's V</td>
<td>0.528</td>
</tr>
<tr>
<td>Not Valid Cases</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Figure 52 Symmetric Measures  Test 1

The Likelihood ratio p-value is 0.036 and lower than 0.05, therefore the null hypothesis is rejected and the alternative hypothesis accepted – There is an association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company. Looking at Cramer’s V value of 0.528, it is possible to say that there is a **very strong** association (University of Toronto, 2016).
• H0: There is no association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.
  
  o H1: There is an association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.

**Chi-Square Tests**

<table>
<thead>
<tr>
<th>Test</th>
<th>Value</th>
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<td>Likelihood Ratio</td>
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<td>N of Valid Cases</td>
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</tbody>
</table>

*a. 18 cells (9.0%) have expected counts less than 5. The minimum expected count is 6.*

Figure 53 Chi-Square test 6

**Symmetric Measures**

<table>
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<tr>
<th>Test</th>
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<tr>
<td>Phi</td>
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<td>Cramer’s V</td>
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<tr>
<td>N of Valid Cases</td>
<td>36</td>
<td></td>
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</tbody>
</table>

Figure 54 Symmetric Measures Test 2

The Likelihood ratio p-value being 0.001 and therefore lower than critical value of 0.05, null hypothesis is rejected and alternative hypothesis accepted – **There is an association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.** Considering the Cramer’s V value of 0.719, the association is **very strong.**

• H0: There is no association between the opinion of customers about environmental performance of a shipping company and their opinion about which aspect of CSR is the most important.
  
  o H1: There is an association between the opinion of customers about environmental performance of a shipping company and their opinion about which aspect of CSR is the most important.
Again, looking at the Likelihood Ratio we find a p-value of 0.05. Therefore, we reject the null hypothesis and accept the alternative one – there is an association between the opinion of customers about environmental performance of a shipping company and their opinion about which aspect of CSR is the most important. The value of Cramer’s V is 0.768, which indicates a very strong association.

- H0: There is no association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a ship cruise.
  - H1: There is an association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a ship cruise.
The p-value of Likelihood ratio is 0,025, which is lower than 0,05. Null hypothesis is rejected and alternative one accepted, which means there is an association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a ship cruise. Furthermore, the value of Cramer’s V of 0,640 shows a very strong association.

- H0: There is no association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a shipping company for importing products.
  - H1: There is an association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a shipping company for importing products.

The Likelihood ratio with p-value of 0,029 is again statistically significant, therefore the alternative hypothesis is accepted and it is possible to say that there is an association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a shipping company for importing products. Cramer’s V with value of 0,742 again suggest a very strong association.
4 Data evaluation

In this chapter, the data acquired in Analytical part of this thesis will be summarized and the outcomes of conducted research commented to provide solid and well-arranged base for formulating recommendations for managerial decision making while acquiring new vessels.

4.1 Scope of profitability

The profitability of its vessels is crucial to every shipping company and these companies aim to maximise it, since their overall profits are directly correlated with operational profitability of a vessel.

In the Analytical part of this work, a quantitative research was conducted with the purpose of exploring and comparing the running costs of vessels powered with MGO, IFO and LNG. MGO vessels were used as a baseline, since they do not need any additional initial investment and are the simplest of all above fuel types. IFO powered ships need to be equipped with a scrubber system, since IFO does not meet the upcoming emission regulations. LNG vessels require a number of additional equipment including special fuel tanks, which largely contribute to the increased price of LNG powered ship. To be able to objectively compare the running costs and economic viability of LNG vessels in comparison to MGO and IFO, four container ship routes were selected for the cost estimation. Using mean fuel prices for the respective regions between which the ship operates, yearly fuel costs and potential savings were calculated in two speed modes – slow steaming and normal speed. Slow steaming was included in this research, because it has been a popular practice among shipping companies since the financial crisis of 2008 and nowadays most container ships operate in a so called “smart” slow steaming mode – using a combination of normal speed and slow steaming to achieve lowest possible fuel consumption while still maintaining reasonable route duration. After establishing the additional capital expenditures for IFO and LNG ships, the yearly fuel costs and possible savings, there were calculated payback periods and internal rates of return for IFO and LNG vessels.

The comparison of fuel costs in chapter 3.2 on all four routes presented a clear winner despite the varying fuel prices across continents and regions. LNG was always the cheapest fuel to operate with the 10.000 TEU container ship selected for the purpose of this research and this was held true in both speed modes.

Payback period, as calculated in chapter 3.4 was the shortest for LNG powered vessels on all four routes, with the closest difference in payback period between LNG and IFO being 5 months on the Asia – South America route in normal speed mode.
Looking at the IRR in chapter 3.5 of IFO and LNG while assuming a ship lifetime of 30 years with the additional capital expenditure as an investment and the possible fuel savings as yearly cashflows, LNG reaches on average 37% IRR while slow steaming and 93% in normal speed mode, whereas IFO380 offers “only” 25% IRR while slow steaming and 61% in normal speed mode. In both options it is possible to say that such an investment is profitable for the company – assuming their WACC is not higher than, for example 25%. While IFO achieves reasonably high IRR as well, the IRR of LNG is still much higher – by 12% while slow steaming and 32% in normal speed mode.

The Analytical part of this thesis also used a qualitative research – a questionnaire – to acquire data for hypotheses testing and gain insight on how shipping companies perceive LNG powered ships in terms of their profitability and compatibility with their CSR strategies, and to find out more on how customers view LNG powered ships, CSR strategies of shipping companies and what are they main criteria while selecting a shipping company.

The outcome of company questionnaires when compared to literature review was quite surprising in some parts, for example while literature suggests that shipping industry is lagging behind in the share of companies having CSR strategies and publishing CSR or ESG reports – according to questionnaire, 90% of shipping companies have CSR strategy and 70% of them publish CSR or ESG reports periodically. The share of reporting companies in S&P 500 Index® is 85%, which means the share of reporting shipping companies is only 15% lower – which is not as significant, considering shipping belongs to group of heavy industries with customers being not as sensitive to CSR or ESG activities of companies. Otherwise the outcome of company questionnaire suggests, that shipping companies are very concerned with environmental aspect of their undertakings and are aware, that their customers value their CSR strategies. The majority of shipping companies also believe in alternative fuels as a replacement to fossil fuels in the future, with LNG being the most promising one.

The questionnaire aimed at customers of shipping companies brought mainly expected results, with price being the most common main criteria for selecting a shipping company. But surprisingly, majority of respondents would be willing (responded with “Yes” or “Maybe”) to pay more for the same service provided by a company with better CSR strategy. Customers also view LNG as a promising future source of power for ships and demand for “green” cruise ships can be identified. The opinion of customers about shipping companies in terms of environmental issues is positive and customers say that shipping companies should prioritize environmental and social aspect in their CSR strategies.
While statistically testing the hypotheses laid out before conducting the questionnaire research, a number of unexpected relationships between variables was uncovered. The hypotheses proven to be true according to statistical testing are following:

- There is no association between whether a shipping company has a CSR strategy and whether it publishes CSR or ESG reports.
- The opinions of shipping companies about how much do customers value their CSR strategies and how significant is the environmental factor in their CSR strategies are not correlated.
- There is no association between the opinion of shipping companies about the future viability of alternative fuels and their strategy for complying with the 2020 sulfur cap.
- There is no association between the opinion of shipping companies about the most feasible alternative fuel and their likely future fuel type choice.
- There is no association between the opinions of shipping companies about OPEX of LNG powered vessels in comparison to MGO and to HFO with scrubber systems.
- There is a very strong association between how often does the customer uses a service of shipping company and their main criteria for choosing a shipping company.
- There is a very strong association between main choosing criteria of customers and their willingness to pay more for services of a company with better CSR strategy.
- There is a very strong association between the opinion of customers about environmental performance of a shipping company and their opinion about which aspect of CSR is the most important.
- There is a very strong association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a ship cruise.
- There is a very strong association between the opinion of customers about the sustainability of LNG and their environmental preferences while selecting a shipping company for importing products.
4.2 Scope of sustainability

The sustainability of LNG can be viewed and explored from two sides – fuel reserves and environmental impact.

When comparing current proven world natural gas reserves to world crude reserves, with the production rate held constant, both fuel sources would be exhausted in approximately the same time. However, there exist known technically extractable reserves of natural gas, which are almost triple the amount of current proven reserves. Keeping this in mind, LNG could be denoted as sustainable source of power in the mid- to long-run.

LNG can be also described as sustainable in the environmental context, with lower CO2 emission than HFO and virtually zero emissions of NOx and SOx and negligible amount of particulate matter. The only environmental challenge connected with LNG are the so-called Total Hydrocarbon Emissions – during the Otto engine cycle, gas can escape into exhaust unburned and since LNG is almost 95% methane, LNG engines are leaking methane into atmosphere. While these leaks are fairly small and methane accounts only for 9% of greenhouse gases, it has 25 times more adverse impact on climate change than CO2, which accounts for 82% of greenhouse gases.
5 Discussion

The objective of this thesis is to formulate accurate, reliable and understandable recommendations for managerial decision making while acquiring new vessels. To accomplish this, a literature review was first conducted (to gain more insight about all the specifics), followed by a quantitative research concerned with fuel costs of various fuel types and a qualitative research in form of questionnaires aimed at shipping companies and their customers, to understand the preferences of these two parties and statistically test various hypotheses.

By the means of Literature review, there was uncovered relevant information about CSR reporting in the shipping industry, possible impact of CSR on financial performance of companies, available fuel types for vessels with their respective advantages and disadvantages and ship newbuilding prices were found out for further use during the quantitative research. As a baseline for this research an MGO powered ship was used and for comparison there were selected two most viable alternative fuel types to use for the purpose of this thesis – which are HFO/IFO with scrubber system and LNG. These fuel types were described in closer detail with their additional capital expenditures and possible risks. The concept of slow steaming, which saw up rise in popularity after financial crisis of 2008 was also described in scope relevant to this research.

In the Analytical part of this thesis, there was conducted a quantitative and qualitative research. The quantitative research was concerned with enumerating yearly fuel costs for MGO, IFO and LNG powered vessels for a 10.000 TEU container ship operating on four selected routes. To objectify the research, mean prices for each region were calculated to accommodate the fuel price differences around the world and evaluate each route as accurately as possible. With this information at hand, fuel price differentials were calculated for each route. Knowing the possible fuel savings, it was also possible to establish the Payback period for both fuel systems on each route, both while slow steaming and with normal speed, and also the Internal rate of return of these systems with assumed ship lifetime of 30 years.

The qualitative research was conducted by means of two questionnaires and statistical testing of hypotheses. First questionnaire was aimed at shipping companies and strived to explore the percentage of CSR reporting, how much do these companies think their customers value the CSR strategy and also their opinion about alternative fuels (in particular LNG) and their knowledge about operating costs of various fuel types. Second one explored the perspective of customers of shipping companies, whether they care about CSR strategies of shipping companies, which aspects of CSR are most important to them or if they consider LNG as viable fuel for the future. Customers were also given two examples, where they had to select a shipping company for vacation in Caribbean and for cargo shipping. The statistical tests
showed no relationship between CSR strategies of shipping companies and their share of reporting or between the opinions of shipping companies about operational costs of LNG powered vessels and their choice of fuel for their future vessels. However, on the customer side, some very strong associations were uncovered, for example their main choosing criteria for a shipping company and their willingness to pay more for a service of a company with better CSR strategy – complete results can be seen in chapter 3.7.

In Chapter 1, a set of research questions was defined to be answered by means of both literature review and data analysis:

**CSR aspects:**

- What is the reason for lower share of CSR reporting companies in the shipping industry?
  - General opinion of shipping industry being a laggard in CSR reporting held true in this research, with the share of CSR reporting companies being lower when compared to S&P 500 Index® companies
  - Author assumes the main reason lies in shipping having the nature of heavy industries, where the customers are less sensitive to CSR strategies and prioritize price while selecting the shipping company – this was proven to be true in the customers questionnaire with cargo shipping, however in cruise shipping the customers tend to prefer CSR strategies and environmental aspects over price

- Is it possible to boost this share by using alternative fuels as an instrument of CSR policy?
  - The alternative fuel used in this research, LNG, has lower CO2 emission than HFO and virtually zero emissions of NOx and SOx and negligible amount of particulate matter. Combined with the outcome of customers questionnaire, where it was identified, that customers define the environmental aspect of CSR as most important for shipping companies and also about 43% of respondents would be willing to pay more for a cruise on “green ship” powered by LNG and tested hypotheses, which showed an association between customers choosing criteria and their willingness to pay more for the same service with better CSR strategy, there is definitely a potential to create more value for the company and stakeholders by using LNG as an instrument of CSR policy.
• Are there any implications against using alternative fuels?
  o As there never is an ideal solution, alternative fuels bring along some drawbacks. In case of LNG, the most notable are less developed infrastructure of bunkering stations, cryogenic temperatures while storing it and methane slip.

• Are LNG powered vessels sustainable in all aspects of CSR?
  o Using the concept of Triple Bottom Line for CSR, which has three pillars – People, Profit and Planet. LNG powered vessels are according to the research outcome and literature review in synergy with all of these three pillars.

Economic aspects:

• Which alternative fuel is most suitable for marine transport as replacement of MGO?
  o In Literature review, virtually all alternative fuels were listed, which could be technically possible to use in the shipping industry. However currently there are only two fuel options, which are considered to be technologically mature and viable in the shipping industry – LNG and biofuel. Biofuel (methanol) still suffers from low production capacity and very high price, therefore LNG is considered to be the most suitable fuel for marine transport as replacement for MGO.

• How profitable are LNG ships in comparison to MGO powered ones?
  o The price of LNG equals on average only to 65% of the price of MGO. That means LNG powered vessels offer 35% fuel savings and even though the additional capital expenditure is quite high, the Payback period in normal speed mode is on average only 13 months and 34 months while slow steaming. The higher profitability of LNG powered vessels can be further illustrated by the IRR with assumed investment lifetime of 30 years, which is 93% with normal speed and 37% while slow steaming. Assuming for example 10% WACC for the company, the investment into LNG powered vessels is very profitable in comparison to MGO.
• How profitable are LNG powered ships in comparison to HFO with scrubber systems?
  o The price of IFO380 and IFO180 amounts to 73% and 78% of the price of MGO, which is on average 10% higher than what we observed with by LNG (65%). This means that LNG powered vessels offer additional 10% of fuel savings than HFO/IFO powered vessels with scrubber systems. Additionally, the Payback period of LNG powered vessels is on average 9 months shorter with normal speed and 23 months shorter while slow steaming. The higher profitability of LNG powered vessels can be also proven by the higher IRR – HFO/IFO powered ships offer on average 57% IRR with normal speed and 23% while slow steaming, comparing these numbers with 93% and 37% of LNG, the IRR of LNG powered vessel is higher by 36% with normal speed and 14% while slow steaming. Therefore, LNG powered vessels are more profitable that HFO/IFO powered ones.

Considering the answers to defined research questions listed above, it can be objectively said, that LNG powered vessels bring along many benefits in all three pillars of Triple Bottom Line

Benefits:
• People can breathe cleaner air
• Profit is proven to be higher due to lower fuel costs
• Planet can profit from lower emissions and no risk of oil spills

According to the outcome of questionnaire research, the demand for “green ships” is fairly high among customers of shipping companies and LNG could be used as a sound instrument of CSR strategy especially for companies operating cruise ships, where customers are less sensitive to price and more interested in CSR and environmental impacts.

Testing the hypotheses laid down in chapter 3.7, no association between variables has been found on the side of shipping companies. However, very strong association were found on the other side by customers. It has been statistically proven, that f.e. the willingness of customer to pay more for a service of company with better CSR strategy is associated with the main choosing criteria of the customers; or between the opinion of customers about LNG sustainability and their choices of cruise ships. Knowing this, it can be generally said that increasing customer awareness about CSR undertakings, strategies, environmental activities and the benefits of
LNG, can bring substantial inflow of customers and it could help to increase the revenues of the shipping company.

Providing the infrastructure of LNG bunkering stations will continue to develop at growing pace, there are no obstacles in wider spread of LNG powered vessels on all routes, both cruise and cargo, and the benefits connected with LNG (economic and environmental) will shine in the light of upcoming emission regulations and high prices of MGO and Ultra Low Sulfur marine oil.

The results of quantitative research in chapter 3.2, which was conducted for a 10,000 TEU container ship with assumed installed engine power of 68,000 kW operating 250 days a year on four different routes, were clear:

LNG was in all cases the most profitable (or cheapest) fuel option to run (in respect of fuel costs alone) by millions of dollars in comparison to its closest competitor, which was in all cases an IFO380 powered vessel equipped with a scrubber system. Considering the Payback period of LNG in worst case scenario, which is slow steaming speed mode with low fuel consumption, the Payback period is as short as 34 months – with assumed ship lifetime of 30 years. Closely connected with the ship lifetime is also IRR, which is 37% while slow steaming and 93% with normal speed – a very profitable investment.

5.1 Research limitations

This thesis of course has some limitations. During the Literature review, author is deliberately simplifying technical aspects of various fuel types, in order to not confuse the reader and stick to the nature of this thesis with respect to CSR and economic implications. Limitations found in the Analytical part are following: Qualitative research consists of sets of questionnaires that suffer from common problems: low response rate, possibility of misunderstanding of the question by the respondent, inability to evaluate the validity of the answers, usefulness of the questionnaire is limited by the clarity of the respondents' opinions, the quality of the questionnaire study is limited by the responsibility of the respondents et cetera. These questionnaires are used for statistical testing of hypotheses drafted by the author. Statistical testing of hypotheses with relatively small sample can produce incorrect findings. Quantitative research focuses on calculating capital and operational costs, the accuracy of which depends on the accuracy of input data. Here lies the limitation of this research, which exists due to the complexity of the calculation itself, the effect of variables outside the scope of the research, the lack of accurate information, the limited number of LNG vessels and the unreliability of forecasting future fuel price developments. For the above reasons, factors that have lesser impact on vessel operating costs may be neglected during the research. In order to limit the impact of
external variables on research, incentives such as special tariffs, subsidies or benefits provided to low-emission ships and additional crew training costs are ignored as they are negligible compared to fuel expenditure and mostly offset each other.

Secondly, this thesis aims to formulate recommendations for managerial decision-making when buying new vessels. Which means identifying and enumerating elements that should help managers choose the type of fuel that is appropriate for their purpose. This work does not intend to create a universally applicable formula for perfect decision making, since each shipping company has different specifics, operates in more or less different environments and situations. Therefore, many elements that this work cannot evaluate must be taken into account in managerial decision-making. There is no perfect answer for all shipping companies.

For the reasons outlined above, the author will list in this thesis useful and accurate information that can be used as a valuable and useful tool to support managerial decision-making when purchasing new vessels.
At last, to conclude this thesis and formulate recommendations for managerial decision making while acquiring new vessels – LNG has proven – based on gathered information and data analysis to be:

- the most profitable fuel option available to date;
- most environmentally sustainable, both in respect of available reserves and exhaust emissions.

Also, there is an identifiable demand for “green ships” among customers, as they tend to start to care more about the environment than about the price of the service itself – which makes LNG powered vessels a powerful instrument of CSR strategy and marketing too. In addition, statistical research has proven associations between customers opinion about LNG and/or environment and their willingness to pay more for the same service from a company with better CSR strategy.

While LNG has some drawbacks in form of:

- cryogenic temperatures;
- larger fuel tanks;
- and methane slip;

any shipping company, which is able to cover the additional capital expenditure (approx. 25% higher), should opt for LNG powered vessel, since it offers higher profitability than all available fuel options and is also environmentally friendly.
7 Bibliography


8 Attachments

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**Figure 62 Asia to Europe with normal speed**
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