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Time Charter Equivalent (TCE) Optimization in Bulk
Shipping.

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Time Charter Equivalent (TCE) Optimization in Dry Bulk Shipping.

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Dedicated to my twins, Iris & Iasonas.

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Abstract

In the dry bulk shipping industry, optimizing vessel selection is critical to maximizing profitability, with the Time Charter Equivalent (TCE) serving as a key performance indicator. The TCE enables shipowners, operators, and charterers to assess the earnings potential of a vessel by comparing voyage revenues with time charter costs, taking into account both market and operational variables. The aim of this thesis is to develop a model for optimizing vessel selection based in the dry bulk shipping, with a particular emphasis on maximizing Time Charter Equivalent (TCE).

The research examines a number of factors affecting TCE, including market conditions, fuel consumption, port charges, scrubber technology and operational efficiency. A multi-criteria decision-making approach is used to integrate these variables into a comprehensive framework that allows the selection of the vessel that offers the highest profitability for a given cargo and route. Different vessel types, sizes, ages, ship designs and cargo requirements are considered in the analysis to determine the optimal match ensuring maximum efficiency and profitability under charter arrangements. Particularly, the study focuses on the comparison between scrubber-fitted and non-scrubber vessels.

Data from both historical and real-time market sources, including freight rates and operating costs, are used to validate the model. Additionally, the study examines the role of emerging technologies and environmental regulations in influencing TCE outcomes. By providing a detailed analysis of how these factors interact, the research provides practical insights for charterers and operators to make informed, profit-maximizing decisions.

Ultimately, the findings of this study contributes to the broader understanding of TCE optimization in the dry bulk shipping industry, offering valuable insights and recommendations for operators and charterers aiming to enhance decision-making processes and operational efficiency in a highly competitive global market.

Keywords

1. Time Charter Equivalent (TCE)
2. Voyage estimation in Bulk Shipping
3. Freight Market Analysis
4. Ship Chartering strategy
5. Profitability Optimization
6. Operational Efficiency

Βελτιστοποίηση του Ισοδύναμου Χρονοναύλωσης (TCE) στη Ναυτιλιακή Βιομηχανία Ξηρού Χύδην Φορτίου.

Σοφία Δ. Κλήμη

Περίληψη

Στη ναυτιλιακή βιομηχανία χύδην φορτίου, η βελτιστοποίηση της επιλογής πλοίων είναι κρίσιμη για τη μεγιστοποίηση της κερδοφορίας, ειδικά όταν χρησιμοποιείται το ισοδύναμο χρονοναύλωσης (TCE) ως βασικός δείκτης απόδοσης. Το TCE επιτρέπει στους πλοιοκτήτες, τους φορείς εκμετάλλευσης και τους ναυλωτές να αξιολογούν τις δυνατότητες δημιουργίας εσόδων από ένα πλοίο συγκρίνοντας τα κέρδη ταξιδιού με το κόστος χρονοναύλωσης, λαμβάνοντας υπόψη τόσο τις μεταβλητές της αγοράς όσο και τις λειτουργικές μεταβλητές. Η παρούσα έρευνα αποσκοπεί στην ανάπτυξη ενός μοντέλου για τη βελτιστοποίηση της επιλογής πλοίων με βάση το TCE, με ιδιαίτερη έμφαση στη ναυτιλία χύδην φορτίου.

Η μελέτη διερευνά μια σειρά παραγόντων που επηρεάζουν το TCE, συμπεριλαμβανομένων των συνθηκών της αγοράς, της κατανάλωσης καυσίμων, των λιμενικών εξόδων και της λειτουργικής αποδοτικότητας. Χρησιμοποιείται μια προσέγγιση λήψης αποφάσεων, βασισμένη σε μια σειρά πολλών και διαφορετικών κριτηρίων, για την ενσωμάτωση αυτών σε ένα ολοκληρωμένο πλαίσιο, που επιτρέπει την επιλογή του πλοίου που προσφέρει την υψηλότερη κερδοφορία για δεδομένο φορτίο και διαδρομή. Η ανάλυση εξετάζει πλοία με διαφορετικά χαρακτηριστικά, όπως το μέγεθος, την ηλικία, τον σχεδιασμό, καθώς και τις προδιαγραφές τους για το φορτίο με στόχο την εξεύρεση του βέλτιστου συνδυασμού πλοίου και φορτίου που θα εξασφαλίζει τη μέγιστη αποδοτικότητα και κερδοφορία στο πλαίσιο της ναύλωσης για ένα συγκεκριμένο ταξίδι.

Για την επικύρωση του μοντέλου χρησιμοποιούνται δεδομένα τόσο από ιστορικές όσο και από πηγές της αγοράς σε πραγματικό χρόνο, συμπεριλαμβανομένων των ναύλων και του λειτουργικού κόστους. Επιπλέον, η μελέτη διερευνά τον ρόλο των αναδυόμενων τεχνολογιών και των περιβαλλοντικών κανονισμών στην επίδραση των αποτελεσμάτων του TCE. Παρέχοντας μια λεπτομερή ανάλυση του τρόπου με τον οποίο αυτοί οι παράγοντες αλληλοεπιδρούν, η έρευνα προσφέρει αξιοποιήσιμες πληροφορίες στους

ναυλωτές και τους φορείς εκμετάλλευσης για τη λήψη τεκμηριωμένων αποφάσεων με στόχο τη μεγιστοποίηση του κέρδους.

Τα ευρήματα της παρούσας έρευνας θα συμβάλουν στην ευρύτερη κατανόηση της βελτιστοποίησης του TCE, συμβάλλοντας στη βελτίωση των διαδικασιών λήψης αποφάσεων στη ναυτιλία χύδην φορτίου και εξασφαλίζοντας πιο αποδοτικές λειτουργίες των πλοίων σε μια ανταγωνιστική παγκόσμια αγορά.

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1. Ισοδύναμο Χρονοναύλωσης
2. Υπολογισμός Ταξιδιού στη Ναυτιλιακή Βιομηχανία Χύδην Φορτίων
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List of Abbreviations & Acronyms

- AWRP – All World Rate of Payment
- B/L – Bill of Lading
- BIMCO – Baltic and International Maritime Council
- BSS – Basis
- C/P – Charter Party
- CIF – Cost, Insurance, and Freight
- COA – Contract of Affreightment
- D/A – Disbursement Account
- DEM – Demurrage
- DES – Despatch
- DWAT or DWT – Deadweight Tonnage
- ETA – Estimated Time of Arrival
- ETC – Estimated Time of Completion
- ETD – Estimated Time of Departure
- FILO – Free In, Liner Out
- FIO – Free In and Out
- FOB – Free on Board
- GENCON – General Charter Party Form
- GT – Gross Tonnage
- ICS – Institute of Chartered Shipbrokers
- IFO – Intermediate Fuel Oil
- IMO – International Maritime Organization
- KNOT – A measurement of speed equal to one nautical mile (6.076 feet) per hour
- LAYCAN – Layday Cancelling Day
- LAYTIME – Time at Charterers disposal for purpose of loading/discharging
- LOA – Length Overall
- LOI – Letter of Indemnity
- LSC – Lump Sum Charter
- LSFO – Low Sulfur Fuel Oil
- M/V – Motor Vessel
- NOR – Notice of Readiness

- P&L – Profit and Loss
- RECAP – Recapitulation of the terms and conditions agreed
- ROB – Remaining on Board
- RPM – Revolutions Per Minute
- SHEX – Saturdays, Holidays Excluded
- SHINC – Saturdays, Holidays Included
- SN– Satellite Navigation
- SOF – Statement of Facts
- SP – Safe Port
- STS – Ship-to-Ship Transfer
- TBN – To Be Named/ To Be Nominated
- TCE – Time Charter Equivalent
- TCP – Time Charter Party
- TCM – Time Charter Market
- VCP – Voyage Charter Party
- VFR – Voyage Fuel Report
- VMS – Voyage Management System
- VSP – Voyage Speed Performance
- WIBON – Whether In Berth or Not
- WOG – Without Guarantee
- WP – Weather Permitting
- WWD – Weather Working Day
- WWR – When, Where Ready
- Z (Zulu) – UTC = GMT

(One Shipbrokers B.V., n.d.)

1. Introduction

1.1 Background of the Study

Shipping has been at the heart of the global economy for over 5,000 years, playing a fundamental role in international trade by enabling the seamless movement of goods and commodities. From ancient times through the modern global economy, shipping has remained the most efficient means of transporting large volumes of goods over long routes. (Stopford, 2009) Today, maritime shipping continues to be the backbone of global trade, carrying more than 80% of the world's goods by volume and more than 70% by value, making it essential for economic development and supply chain connectivity. (UNCTAD, 2017)

The shipping industry operates within a complex framework consisting of several core components: the sea transport system, the merchant fleet, the ports and the shipping companies that manage the logistics. Together, these components form a highly efficient system that connects producers and consumers across the globe. (Notteboom et al., 2022)

Bulk shipping, a significant segment of the global shipping industry, facilitates the transportation of substantial quantities of major commodities including coal, iron, ore, grain and oil, as well as minor commodities such as steel products, sugar, cement, fertilizers and metal scrap. The transportation of these commodities is of critical importance for various industries, including those of manufacturing, energy production and construction. Bulk shipping's ability to transport essential goods over long distances ensures that regions with limited local supplies have access to the materials necessary for sustaining industrial activity. This in turn, boosts the domestic demand and employment rates, contributing positively to a country's economic growth and development (Shi & Li, 2017).

A subset of this sector, the dry bulk shipping, focuses specifically on transporting dry commodities, essential for global supply chains, such as metals and agricultural products. The economic importance of dry bulk shipping lies in its efficiency and ability to reduce transportation costs by leveraging economies of scale, enabling the cost-effective movement of large volumes of cargo. Despite its critical role in global trade, the dry bulk shipping industry faces significant challenges, particularly in managing profitability as it operates in a competitive market environment, heavily influenced by the dynamics of global trade. One of the main challenges is market volatility. The dry bulk shipping market

is closely linked to demand and supply dynamics, with freight rates as a key indicator. During periods of overcapacity, when there are more vessels than needed, freight rates decrease, squeezing profit margins. Conversely, when freight rates rise, profitability increases. The dry bulk shipping's economic significance is deeply tied to its ability to adjust to the cyclical nature of the market, necessitating precise operational and strategic fleet management to navigate competitive freight rates and tight profit margins (Tsoulakis, 2005)

The industry also includes four interconnected sub-markets: freight, new building, sale and purchase and demolition markets. Together, these markets influence fleet size and shipping capacity, impacting overall industry profitability. (Lun & Quaddus, 2009)

It is crucial to underscore the pivotal role of the freight market in the generation of revenue in the sea transportation. This enables shippers to secure transportation services through contractual agreements, known as charter parties. A charter party is a legal contract, that outlines the terms and conditions under which a vessel is chartered and defines the rights, obligation, costs and risks shared between the shipowners and charterers. There are three main types of charter parties, the voyage charter, the time charter and the bareboat charter, each tailored to address distinct operational and commercial requirements. (Plomaritou, 2014)

In addition to market volatility, the industry faces high operational costs. Bunker costs are a major component of operating expenses, and fluctuations in oil prices can have a direct impact on profitability requiring strategic financial management to optimize performance. (Kang et al., 2015) Shipping companies also incur fixed costs such as port charges, maintenance and crew wages that remain constant regardless of market conditions.

Furthermore, the industry is subject to increasing environmental regulations aimed at reducing emissions, which require shipping companies to invest in cleaner technologies and more innovated and efficient vessels, further increasing operational costs. (Abouarghoub & Haider, 2019)

Considering the aforementioned factors that affect the dry bulk industry, the pre-voyage calculation or voyage estimation is of paramount importance for chartering managers, ship-owners and operators alike. It serves as a crucial tool for evaluating the profitability of transporting specific cargoes, whereby the potential earnings are estimated in terms of Usd per day and expressed as the Time Charter Equivalent (TCE). In a voyage charter, the

vessel is fixed to carry cargo from loading to discharge ports, with the ship-owner bearing all associated voyage costs, including fuel, port and canal dues and insurance. The accurate calculation of voyage estimation is a time-consuming process. The process commences with the collection of comprehensive data on cargo specifics, port restrictions, vessel suitability and current bunker prices. Cost calculations then entail the selection of an optimal sea route, taking into account a number of factors such as vessel size, weather conditions, piracy risks and canal congestion. By comparing the projected profits of different cargoes and vessel combinations, managers can make well-informed decisions and select the most profitable and efficient options for each voyage. (Omholt-Jensen, 2024)

1.2 Problem Statement.

The dry bulk shipping industry operates in a highly competitive and volatile environment, where the optimization of profitability is essential to sustain a competitive edge. One principal metric for evaluating profitability is the TCE, a standardized measure that enables ship-owners and operators to assess potential earnings across different voyages and vessel types. The conversion of spot market earnings to an equivalent time charter rate allows for comparisons across diverse operational conditions and voyage distances. (Apostolou et al., 2023) Nevertheless, the complexity of accurately forecasting and optimizing TCE presents a considerable challenge, due to the multitude of variables involved. These include operational factors, market rates and specific vessel characteristics, each of which impacts the overall efficiency and cost-effectiveness of voyages. (Molvik & Stafseng, 2018)

Fluctuating freight rates, volatile fuel prices and unpredictable port costs are the key factors contributing to inaccuracies in TCE optimization. These external variables are compounded by operational complexities, including vessel specific attributes such as size, speed and fuel efficiency, voyage specific constraints, like weather conditions and route distances and cargo requirements. Inaccurate forecasting of these factors frequently results in suboptimal vessel selection, which in turn leads to lower profitability and increase operational risks. (Kavussanos et al., 2021)

The traditional methods for vessel selection usually depend on static models or historical averages and consequently lack an integrated approach that simultaneously considers the

various factors to achieve the greatest profitability for specific cargoes. These oversimplified approaches result in errors in voyage estimation and in the deployment of vessels that underperform in terms of profitability, increasing the financial distress on operators.

Recent studies have highlighted the necessity for a systematic and data-driven approach that incorporates all relevant variables to enhance vessel selection, facilitate TCE-based decision-making and ensure competitive advantage and sustainability in a highly volatile market. As illustrated by Alizadeh and Nomikos (2011) combining voyage cost models with real-time market can lead to improved vessel selection and routing decisions. The growing use of digital tools has reduced inaccuracies in calculations and increased the role of data-driven decision making in vessel operations. However, to realize their full potential in TCE optimization, these tools need to integrate industry expertise to overcome the limitations of purely data-driven models. If a model produces predictions that contradict widely accepted industry beliefs, it risks losing credibility and trust among professionals. To improve reliability, models should incorporate practical constraints and follow logical industry trends, such as the fact that ship risk generally increases with age and that fuel consumption rises sharply at higher speeds. Ensuring alignment with these real-world principles enhances reliability and makes models more applicable to voyage estimation and ship selection. While digital advances improve accuracy, their true effectiveness depends on their ability to reflect the realities of maritime operations. Data alone is insufficient; models must be built with shipping expertise to ensure accuracy, credibility and relevance. (Incorporating Shipping Domain Knowledge into Data-Driven Models. 179-189, 2022)

In response to this gap in the market, this research proposes a methodology based on voyage estimation to identify the optimal vessel for a specific cargo contract. The model uses Microsoft Excel to simulate voyage costs and revenues based on real-time and historical data. Excel enables the creation of customizable TCE calculations by integrating cost variables and operational constraints. In addition, to increase the accuracy of the analysis, it is necessary to incorporate various software and platforms to assess current market rates, vessel databases and route optimization. (Jia et al., 2019) This approach allows operators to perform a thorough and objective analysis while identifying operational inconsistencies through real-time monitoring. By comparing the vessels'

characteristics, it facilitates the selection of the vessel that offers the highest TCE under a given set of market and operational conditions.

By concentrating on a data-driven model for TCE optimization, this study aims to provide a structured framework for the vessel selection that addresses the current market volatility and operational complexity. It is anticipated that the findings will enhance decision-making processes in dry bulk shipping, facilitating more accurate and profitable vessel deployment.

1.3 Research Objectives

In the dry bulk shipping industry, the optimization of vessel selection is a critical task for the charterers and shipowners aiming to enhance profitability. This research focuses on the development of a comprehensive model for optimizing vessel selection using Time Charter Equivalent (TCE) as the central metric. The objective is to integrate multiple factors, including freight rates, fuel consumption, port charges and vessel operational efficiency into a decision-making framework that will improve vessel selection and profitability for specific cargo type and routes.

A primary objective is a comparative analysis between scrubber and non-scrubber vessel voyage estimations. The study examines the main drivers of TCE, in particular differences in fuel price and operating costs that affect vessel profitability. Using a multi-criteria decision making approach, the model will identify the optimal vessel choice by balancing these operational and market factors. In addition, the model will be validated using both historical and real-time data, ensuring its practical application for real-world decisions.

Furthermore, the research examines the growing impact of environmental regulations and technological advancements on operational costs and vessel selection strategies. By understanding how these external factors influence TCE, the study aims to provide practical recommendations for adapting to the evolving shipping environment. (Galić et al., 2017)

Ultimately, the findings will provide valuable insights for charterers, shipowners and operators, offering a data-driven tool to make informed decisions in vessel selection and maximize profitability. This study contributes to the broader literature on maritime operations and TCE optimization, helping stakeholders navigate complex market conditions and operational variables in an increasingly competitive and regulated global market.

1.4 Scope

The scope of this study is to optimize vessel selection in the dry bulk shipping industry by developing a model based on the Time Charter Equivalent (TCE) metric. Specifically, the study designed to compare the performance of a scrubber-equipped with that of a non-scrubber-equipped Ultramax vessel when assigned to a specific voyage under a voyage charter.

The analysis is conducted through a detailed voyage estimation, which incorporates a number of commercial and operational variables. These include, but not limited to, freight rates, fuel consumption, port charges, vessel speed and overall voyage duration. The aim is to determine which vessel configuration produces the most favorable TCE under given market and operational conditions.

This study is limited to the dry bulk segment and focuses on the Ultramax vessel size, which is commonly used for a wide range of bulk commodities. The scope does not extend to other vessel classes or other shipping segments. The focus remains on a single voyage scenario, allowing a more controlled comparison between vessel types.

The voyage estimation process and comparative TCE analysis are carried out entirely in Microsoft Excel. This decision reflects an industry-relevant and accessible approach, suitable for practical use by shipping professionals without the need for advanced software tools or programming skills.

By limiting the scope in this way, the study aims to provide practical insights into the financial implications of vessel selection decisions, especially within the context of environmental regulations and fuel strategy considerations related to the scrubber installation.

2. Literature Review

The shipping industry operates through four closely connected markets, each serving a unique role. The freight market handles sea transport services while the demolition market deals with the scrapping of old ships. The newbuilding market is the site of the ordering and construction of new ships, and the Sales and Purchase market (S&P) focuses on the trading of second hand vessels. (Lun et al., 2013)

The present study focuses on the freight market as it is the primary driver of the shipping industry and a critical aspect in optimizing the Time Charter Equivalent (TCE). The freight market determines the freight rates through the interaction of supply and demand for the vessel capacity. It also establishes the framework for the vessel selection and deployment. (Kasimati & Veraros, 2024)

This study analyzes its dynamics to identify the operational and market factors that influence TCE performance. Given its volatility, ship-owners face substantial financial risks and uncertainties, including fluctuations in freight rates, oil prices and foreign exchange rates, which in turn have a further impact on decision-making in vessel deployment and profitability. (Kavussanos & Visvikis, 2006)

The complexity of the shipping industry stem from the interplay of multiple stakeholders, the freight market volatility and the dynamic contractual agreements. (Lun et al., 2010)

The dry bulk shipping market is characterized by a significant number of small shipowners, with no barriers to entry for new participants. Transactions are highly transparent, which serves as a testament to its strong example of a perfectly competitive market. (Yijie et al., 2018)

The roles and interactions of the main participants in the shipping process, namely charterers, shipowners, operators and brokers, collectively contribute to the efficient transportation of goods under contractual agreements. At the same time, according to the study by (Adland et al., 2016), these interactions play a crucial role in shaping freight rates, as both market conditions and the specific characteristics of charterers and shipowners influence pricing dynamics. In the Capesize market, both the identity of the charterer and the nature of its relationship with shipowners have a significant impact on freight rates, underscoring the importance of individual negotiations and contractual arrangements. Furthermore, the findings of the study show that the dry bulk market is not as uniform as traditionally assumed, with factors such as creditworthiness, negotiation

strategies and company specific characteristics contributing to price variation and adding to the complexity of freight rate formation. (Adland et al., 2016)

The study by (Efes et al., 2019) provides an in depth analysis of the complex interplay between supply, demand and freight rates in the dry bulk shipping market, focusing on China's trade as an important demand driver and the global dry bulk fleet as the supply factor. The demand, measured by trade volume, is driven by the global economic activity and the movement of key commodities like iron, ore and coal. On the other hand, the supply is characterized by the size and productivity of the fleet, yet it is inherently inflexible in the short term due to the extended lead times for shipbuilding, which range from one to three years. This inflexibility frequently results in sharp fluctuations in freight rates when demand rises rapidly, as capacity cannot adapt promptly.

Their findings show that a 1% increase in China's trade volume results in a 2.54% increase in Baltic Dry Index (BDI), highlighting the direct link between increased trade activity and higher freight rate. China's rapid industrialization, particularly between 2003 and 2008, is an example of this relationship, as the surge in imports of raw materials during this period has pushed freight rates to record highs. However, the study also underscores the negative impact of oversupply on freight rates. A 1% increase in fleet size leads to a 5.66% decrease in BDI, demonstrating the market's heightened sensitivity to supply-side changes. This imbalance was clearly evident in the post-2008 financial crisis, when overinvestment in fleet expansion during the preceding boom years led to an oversupplied market. The combination of slower demand growth and excess capacity led to a collapse in freight rates.

The authors conclude that the freight market serves as a regulatory mechanism, adjusting prices to balance supply and demand. Shipowners and other stakeholders need to carefully manage the fleet capacity and anticipate market trends. Strategic decision-making, especially during boom periods, is essential to avoid the dangers of overcapacity, which can undermine long-term profitability (Efes et al., 2019).

The dry bulk shipping industry is characterized by cyclical market patterns that affect freight rates, vessel valuations and investment strategies. The bulk shipping cycle consists of four distinct phases: trough, recovery, peak and collapse. These cycles are driven by global economic trends, trade flows and geopolitical factors (Stopford, 1997).

Scarsi (2007) further elaborates on market cycles, emphasizing that shipowners must strategically time their investments to maximize profitability. The cyclical nature of the

shipping industry creates opportunities for those who adopt a counter-cyclical approach by investing in ships when prices are low and selling when demand is high. However, despite having access to extensive market data and financial models, shipowners often make suboptimal decisions due to psychological biases and misinterpretations of market trends. Rather than employing strategic decision-making, shipowners often fall into common traps like following herd behavior, overestimating their ability to predict market trends or relying on recent trends rather than long-term fundamentals. These biases frequently result in mistimed investments, with shipowners ordering new vessels when prices are at their peak and selling them at market troughs, ultimately reducing profitability.

A notable case study examined by Scarsi (2007) involves the Handysize segment. During the period between 1996 and 2002, this segment experienced a period of neglect, despite the presence of favorable conditions, including low shipbuilding prices and an aging fleet. However, as the shipping market expanded from 2003 to 2006, shipowners belatedly rushed to invest in handysize vessels, by which time shipyards slots were already full and ship prices had surged. Consequently, only those who had invested early benefited from the subsequent supply shortage and increased freight rates. This case underscores the critical importance of timely and well-informed decision-making in the shipping industry. Furthermore, Scarsi's analysis reinforces the inherent cyclicity of bulk shipping, emphasizing that success depends on a shipowner's ability to accurately interpret market signals and act proactively. Those who can successfully navigate these cycles, avoiding impulsive reactions and psychological biases are more likely to achieve sustained profitability (Scarsi, 2007).

The shipping process is governed by contracts tailored to specific operational needs. These contracts, commonly known as Charter Parties (CPs), are legally binding and internationally recognized documents. The charter party details the vessel's specifications, freight/hire terms, safe port obligations, seaworthiness, cargo handling terms and indemnities. They define the legal and operational responsibilities of the parties involved, the shipowners and charterers. (Plomaritou, 2014)'s study focuses on the allocation of liabilities, costs, risks and duties in voyage charters, time charters and bareboat charters according to English Common Law. It examines how these responsibilities are structured within the chartering process, which includes the pre-fixture, fixture, execution and post-fixture stages. In a voyage charter, the shipowner agrees to transport a specific cargo between designated ports for a fixed freight rate, usually calculated per ton of cargo. The

shipowner covers all the voyage-related costs, the operating and capital expenses, while the charter is responsible for providing the cargo and covering loading, stowing, trimming and discharging costs under FIOST (Free In/Out, Stowed and Trimmed) terms. In time charter, the charterer hires the vessel for a fixed period and assumes the commercial control, paying for fuel and port expenses, while the shipowner remains responsible for the technical management of the vessel. Under bareboat charter the vessel is chartered without crew or supplies, with the charterer being responsible for managing the vessel and covering crew and maintenance costs and the shipowner only the capital costs. In addition, there are some other chartering forms, such as contract of affreightment (COA), long-term contracts which involve multiple voyage charters, with rates determined by a fixed quantity of cargo or a certain number of voyages.

Several clauses are included in the charter parties to address specific operational scenarios:

- Laytime defines the time allocated for loading or unloading operations
- Demurrage compensates the shipowner for delays in port operations beyond the agreed laytime
- Dispatch is a reduced rate paid by the shipowner when port operations are completed faster than the agreed laytime. It rewards charterers for completing operations ahead of schedule.
- Notice of Readiness (NOR) is a formal notification indicating the vessel's readiness for loading or unloading.
- Virtual arrival allows adjustments to a vessel's speed and arrival time to reduce fuel consumption and emissions when delays at the destination port are known.

(Plomaritou, 2014) emphasizes that a well-structured charter party is critical to mitigating disputes, optimizing cost allocation and ensuring efficient vessel operation in the shipping industry.

After analyzing the various types of charter parties, this study will focus specifically on voyage charters. This focus is driven by the need to analyze voyage estimation for optimal vessel deployment, which is critical for optimizing the TCE in bulk shipping operations.

The voyage estimation process is a crucial element in the optimization of vessel selection and TCE in the dry bulk shipping. Its objective is to forecast the total costs and revenues related to the voyage and allow ship operators to ascertain the viability of a specific

voyage and to evaluate alternative route options. Despite the fact that different owners may approach the process in a unique way, the fundamental principles remain constant.

A principal component of voyage estimation is the freight revenue calculation, which depends on a number of factors, including the specific type of cargo, the distance and the prevailing freight rates. The revenue is calculated by estimating the cargo capacity and multiplying it by the applicable freight rate. Nevertheless, factors such as the vessel deadweight (DWT), draft restrictions at loading or discharging ports, canal restrictions and the cargo cubic volume can limit the cargo carried. Additionally, seasonal load line restrictions, such as those designated with winter, summer or tropical zones, may further influence the outcome. (Collins, 2000)

Among the various factors considered, a vessel's specifications, particularly its DWT, have a significant impact on its economic and operational performance. An imbalance in DWT can create inefficiencies; excessive DWT increases fuel consumption and operating costs, while insufficient deadweight limits revenue potential by restricting cargo capacity. By selecting the right DWT that aligns with their vessel's specific requirements, operators can minimize unnecessary expenditure, improve fuel efficiency and enhance the overall economic viability of the vessel in the maritime transport. (Michalski, 2014)

In addition, a variety of operational expenses must be assessed, including fuel costs, port charges and canal fees. The fuel costs (bunkers) represent the most significant variable cost in the shipping, with oil-derived bunker fuel accounting for approximately 34-44% of total operating costs. (Notteboom & Vernimmen, 2009). Bunker costs depend on the vessel type and size, the route, fuel type and market fluctuations in fuel prices. Accurate estimation of fuel consumption is of the utmost importance in ensuring precise voyage costing. This process begins with assessment of specific fuel consumption based on vessel design and engine efficiency. The total fuel required is then calculated by taking into account the voyage distance, while further adjustments are made to account for speed variations and potential weather challenges, particularly if the vessel is expected to encounter rough seas or must adhere to a specific schedule. (Omholt-Jensen, 2024)

While fuel consumption plays a critical role in voyage costing, its impact on freight rates is not uniform across all market conditions. The relationship between bunker prices and freight rates in the dry bulk shipping market is subject to variation depending on market dynamics. (Açık & Ayaz, 2018) conducted a time-varying causality analysis, identifying 24 causality periods, ranging from 1 to 13 months, in which bunker prices significantly

influenced freight rates. The findings of this study showed that the influence is strongest during market downturns, as reflected in the Baltic Dry Index (BDI). In such periods, when freight rates are falling, ship-owners and charterers tend to adjust their pricing strategies based on operating costs. Conversely, during periods of high demand, bunker price fluctuations have less of an impact on freight rates as market demand becomes the primary price driver. These findings highlight the cyclical nature of cost-price relationships within the shipping industry and reinforce the necessity of incorporating market conditions into TCE optimization models.

The cost of a voyage is directly proportional to the fuel consumption, which in turn is a function of the vessel's speed. The selection of an appropriate speed for a vessel is a decision that is not as straightforward as it may appear. The relationship between vessel speed and fuel consumption is non-linear, with fuel use increasing exponentially at higher speeds. While reducing vessel speed may lower fuel costs, it can extend voyage duration. (Hellenic Shipping News Worldwide, 2015)

The choice of speed has a notable influence on the TCE. In certain instances, charterers may require the vessel to proceed at maximum speed to the designated discharging ports. This stipulation is typically necessitated by the need to either meet deadlines, secure berths or avoid the risk of stock-outs of the cargo carried by the ship at the receiver's site. Higher speeds increase fuel consumption and therefore raising voyage costs. Sailing slower saves money on fuel, which increases profit, but also spreads profit over more days, potentially lowering overall earnings. Psaraftis and Kontovas (2013) offer a thorough overview of speed models in transportation research, emphasizing the impact of market conditions and fuel prices on vessel speeds. Specifically, they observe that during periods of market growth or when fuel prices are low, owners tend to navigate at full speed, while slower speeds are preferred in low markets or high fuel prices to lower fuel consumption and emissions. (Psaraftis & Kontovas, 2013) Similarly, Acik and Baser's (2018) analysis revealed that shipowners reduce speed in response to rising fuel prices but do not immediately increase speed when prices decline as freight market conditions influence such operational decisions. This reflects an asymmetric causality in the dry bulk sector. (Acik & Baser, 2018)

In terms of selecting the appropriate speed, the timing of a vessel's arrival at the load port is another factor to consider when assessing the TCE. An early arrival results in increased costs due to the idle waiting time and additional fuel consumption. On the other hand, an

arrival just in time (JIT) reduces the unnecessary costs while ensuring readiness for cargo loading. During ballast voyages, vessels typically sail at economical speeds to designated waypoints, adjusting speed after securing a voyage charter to align with contracted cargo loading dates (Hellenic Shipping News Worldwide, 2015).

A study by Lu et al., (2013) highlights the important role of voyage optimization, as a strategy to improve energy efficiency and reduce Green House Gas (GHG) emissions in shipping. This approach involves predicting ship performance under different sea conditions and using this information to select optimal routes that balance minimizing voyage time, ensuring safety and reducing fuel consumption. This aligns with international initiatives such as the Ship Energy Efficiency Management Plan (SEEMP), which aims to reduce environmental impact while enhancing operational efficiency. The process relies on real-time data, including weather forecasts, ocean currents and ship-specific performance characteristics, to identify the most efficient routes. Lu et al. (2013) further emphasize the importance of accurate predictions, and their research introduces a modified empirical method for Suez-Max oil tankers, that improves the accuracy of fuel consumption and resistance predictions compared to previous models.

Ahoka (2019) further support this, demonstrating fuel savings, emission reductions and improved revenues through just in time (JIT) operations, weather routing and speed optimization. A case study was conducted to highlight the impact of these strategies and the results showed fuel savings and emission reductions of up to 28% along with an increase in shipowners' daily revenue performance of 7.2% to 17.8%. However, to fully realize these benefits, operational processes must be adapted to align the incentives of all stakeholders. This includes the creation of equitable mechanisms for the sharing of benefits between shipowners and charterers, improvements in port planning and the adoption of real-time data sharing systems.(Ahokas, 2019)

In a recent publication, Apostolou, Lagoudis and Theotokas (2023) present a comprehensive framework for the optimization of TCE in Capesize vessels, with a particular focus on the balancing of economic performance with environmental compliance. The research findings emphasise the significance of aligning operational speeds with the International Maritime Organization's (IMO) carbon intensity indicator (CII) requirements. This approach has the potential to enhance profitability while avoiding penalties and maintaining competitiveness. Furthermore, the study highlights the influence of fluctuating bunker prices on freight rates, thereby encouraging operators to implement

flexible economic strategies that account for fuel price volatility. The utilization of eco-friendly technologies, such as eco-electronic engines and scrubbers, is also underscored as a means of improving CII compliance and ensuring long-term operational sustainability. By optimizing speeds in relation to TCE and environmental standards, operators can achieve superior profitability, operational efficiency and a competitive advantage. Additionally, the findings provide a foundation for future research into models that incorporate various vessel types, routes and economic conditions, offering further opportunities for improving decision-making in vessel selection and voyage planning. (Apostolou et al., 2023)

Sigalas (2022) examines the financial implications of the IMO 2020 regulation on the dry bulk shipping. The regulation, designed to reduce sulphur emissions, imposed significant costs on shipowners through higher fuel prices or investments in scrubbers. As these additional costs were absorbed by shipowners rather than passed on to charterers, the regulation disrupted the traditional business paradigm. The findings indicate that the increase in fuel costs resulting from the use of low-sulphur fuel oil (LSFO) led to a decline in TCE rates, thereby significantly reducing shipowner's profit margins. In order to comply with the regulation, shipowners were faced with two main strategies: to use the more expensive LSFO without any capital investment or to install scrubbers, (exhaust gas cleaning system, which reduces sulphur oxides emissions from the engines), to continue to use the cheaper high-sulphur fuel oil (HSFO). Slow steaming, a strategy that reduces vessel speed to decrease fuel consumption, emerged as a mitigation tactic but it introduced trade-offs, such as an increase in voyage durations and a reduction in annual revenues. Utilizing a mathematical model, the research revealed the sensitivity of TCE to fuel prices and speed, identifying an optimal speed for a specific fuel price that ensures maximum profitability. These findings highlight the necessity for fairer emission-related regulations that fairly distribute financial impacts across stakeholders. (Sigalas, 2022)

Innovative technologies further support voyage optimization. Psaraftis (2019) explores the potential of green ship technologies to enhance energy efficiency and reduce the environmental impact of maritime operations, emphasising their relevance to operational and economic optimization. Among the innovations examined are hull optimization, energy-saving devices (ESDs) and the integration of renewable energy. Advanced Computational Fluid Dynamics (CFD) tool are important in designing optimized hull forms that minimize hydrodynamic resistance, thereby lowering fuel consumption,

particularly for vessels operating in specific trade routes. Furthermore, the integration of ESDs, such as air lubrication systems and propeller fins, significantly improve propulsion efficiency by reducing energy losses. Trials have shown the potential for fuel savings of up to 10%. The use of renewable energy technologies, including solar panels and wind-assisted propulsion systems, serves to further complement traditional propulsion methods, providing sustainable alternatives for reducing emissions. Despite the high initial capital costs associated with these technologies, they are aligned with the dual objectives of minimizing fuel consumption and adhering to environmental regulations. (Psaraftis, 2019)

The shipping market is characterized by inherent volatility due to global supply and demand imbalances. However, the movement of each cargo creates a local “mini-market” determined by the number of available vessels within a specific time and distance from the loading port. A higher concentration of available vessels tends to drive freight rates down, while limited availability can drive rates up. This localized competition underscores the importance of strategic vessel positioning. As a result, a vessel’s competitiveness is affected not only by global market conditions but also its position relative to potential cargoes. To this end, shipowners must leverage real-time market intelligence to strategically position their vessels to ensure they are well placed to secure high-value charters. Collaboration with brokers and the use of advanced data can improve market visibility and optimize TCE. (Hellenic Shipping News Worldwide, 2015)

Accurate voyage estimation requires a thorough market analysis, gaining insight into route-specific costs, monitoring freight rate trends and carefully addressing the commercial risks inherent in the chartering process from pre-fixture negotiations to post-fixture claims handling. Legal complexities in charter parties (C/Ps) and evolving environmental regulations pose additional challenges to maintaining optimal TCE. Therefore, shipping companies must adopt strategic planning and risk management practices to navigate these complexities effectively. (Wereley, 2015)

These risks are further examined by Plomaritou and Nikolaidis (2016) and encompass market volatility, operational uncertainties and financial exposure. The cyclicity of freight rates, which is influenced by factors such as political events, technological advances and economic trends, is critical in determining charter strategies. For instance, vessels chartered on the spot market expose shipowners to fluctuating rate, while long term charters reduce risk but limit the potential gain. In addition, operational risks,

including bunker price volatility, delays and safety regulations compliance, can also have an impact on voyage costs and consequently, TCE outcomes. Implementing effective risk mitigation strategies, such as insurance, hedging and forecasting is essential for minimizing financial losses and ensuring optimal vessel deployment. (Plomaritou & Nikolaidis, 2016)

In the field of maritime transportation and trade, the estimation of cargo payload volumes for vessels has historically posed significant challenges due to the lack of transparency within the shipping industry. This has prompted researchers to propose novel approaches to address this critical gap in data. One such approach, outlined by Jia et al., (2019), utilizes draught measurements reported via the Automatic Identification System (AIS). This innovative method leverages the real time vessel identity, location and draught data provided by the AIS, thereby offering a practical and much-needed solution. Their research demonstrates that combining draught data with vessel and voyage-specific characteristics enables high-accuracy payload estimation. (Jia et al., 2019)

In light of the insights offered by Kanamoto et al. (2021), the utilization of advanced data analytical techniques and vessel management strategies represents a valuable means to enhance TCE. The AIS has been identified as a key tool for improving voyage estimations. This is achieved by tracking vessel movements, identifying ports of call and estimating cargo flows for major commodities such as iron ore, coal and grains. Accurate estimation of a voyage's duration can help to reduce inefficiencies such as empty sailing, optimize vessel deployment and minimize the number of ballast legs. Furthermore, the integrating AIS data with regression analysis quantifies the impacts of trade volumes, draft limits and voyage distances on vessel selection. High trade volumes encourage the use of larger vessels, offering economies of scale, while longer voyage distances justify the deployment of vessels with higher capacities. In addition, port draft restrictions influence vessel feasibility, highlighting the need for a balance between operational costs and cargo revenue. (Kanamoto et al., 2021)

Building on this, ship size and voyage distance significantly influence TCE deviations and thus voyage efficiency. (Kassembe & Gang Z., 2013) Larger vessels tend to experience greater efficiency losses on shorter voyages, whereas the impact of these deviations is reduced on longer voyages. However, while longer voyages may generate higher freight revenues, they also incur higher costs, which may offset the gains and affect TCE. Additionally, uncertainties in voyage time and bunker costs contribute to TCE variations,

with greater variations leading to more substantial reductions in profitability. Even minor increases in freight rates can mitigate efficiency losses, emphasizing the importance of market-driven vessel selection. (Vyshnevskaya & Vishnevsky, 2017)

Freight market indices, such as Baltic Dry Index (BDI), are essential in anticipating market volatility and guiding chartering decisions. By aligning vessel schedules and contract negotiations with these market conditions, operators can secure higher freight rates, which directly improve TCE. Additionally, integrating port accessibility data with market indices contribute to a strategic vessel deployment and enhance profitability in the dynamic dry bulk shipping. A systematic approach to vessel selection is essential for maximizing efficiency and ensuring optimal deployment. The multinomial logit model proposed by Kanamoto et al., (2021) provides a structured methodology for identifying the most cost-effective and profitable vessel types, by incorporating seasonal and regional factors, along with an analysis of global cargo flows. When combined with comprehensive port-to-port information, including vessel arrival and departure details, draft changes and commodity data, this approach enables more precise cargo operations. AIS-derived vessel movement data further enhances this process by allowing detailed classification of single and multi-commodity ports and berths, as well as the creation of accurate commodity handling records for each berth. This integration of market insights, vessel selection models and port intelligence improves cargo planning, strengthens voyage estimation and optimizes vessel deployment. Ultimately, these strategies contribute to a more data-driven and sustainable approach to TCE optimization in dry bulk shipping. (Kanamoto et al., 2021)

Following a thorough analysis of the factors that affect the voyage estimation, the TCE for each vessel is calculated to determine the most suitable vessel for the specific cargo contract. A comprehensive understanding of TCE necessitates an examination of its calculation, the factors that influence it and the implications of these factors for chartering strategies

The TCE is a widely used performance metric in the dry bulk shipping that reflects the net daily revenue generated by a vessel over a given voyage. It provides a standardized method of converting the spot freight rate into a daily hire rate for a voyage. The TCE is essential for evaluating voyage profitability and comparing vessel efficiency across different routes and market conditions. It is used in the voyage estimation process and derived by deducting the voyage-related cost from the total freight revenue, and dividing

by the total voyage duration, assuming the vessel operates on a time charter basis. The formula can be expressed as:

$$\text{TCE/day} = \frac{\text{Net freight (Freight revenue - voyage costs)}}{\text{Total voyage duration}} \quad (\text{Hellenic Shipping News Worldwide, 2015})$$

Where, freight revenue is the total income from the voyage, which includes freight income, demurrage and any other earnings related to the voyage. Freight income is the gross freight revenue, which is calculating by multiplying freight \$/per metric ton by total cargo quantity in MT, adjusted for a standard 5% commission.

The brokerage commission is a fee paid to brokers for facilitating the charter agreement between shipowners and charterers. In voyage chartering, the brokerage commission is a percentage of the freight earned, paid by the shipowner, while in time chartering it is a percentage of the hire rate, deducted from the daily hire payments over the charter period.

Voyage costs are classified as variable costs, which are subject to fluctuations depending on the particulars of a given voyage. Such costs include a range of operational costs such as bunker fuel expenses, port fees, canal transit tolls and other voyage-related expenditures. The variability of these costs is influenced by various factors, including the vessel's speed, the cargo's condition and prevailing weather conditions during the voyage.

Voyage duration refers to period that a vessel spends on the voyage, from its initial departure point to its final destination, where cargo is discharged, including the repositioning time. The total voyage duration includes both laden segments, during which the vessel carries cargo and the ballast segment, during which the vessel returns to port empty in order to load the next cargo.

TCE calculations differentiate between scrubber and non-scrubber vessels, reflecting the two-tiered market dynamics following the IMO 2020 sulphur cap regulations. Scrubber-fitted vessels typically use 3.5% high- sulphur fuel oil (HSFO) alongside marine gas oil (MGO), while non-scrubber fitted vessels rely on the more expensive 0.5% low-sulphur oil (LSFO) and MGO. (IMO, 2021)

Therefore, the variables and the different fuel types that are used in TCE calculation are:

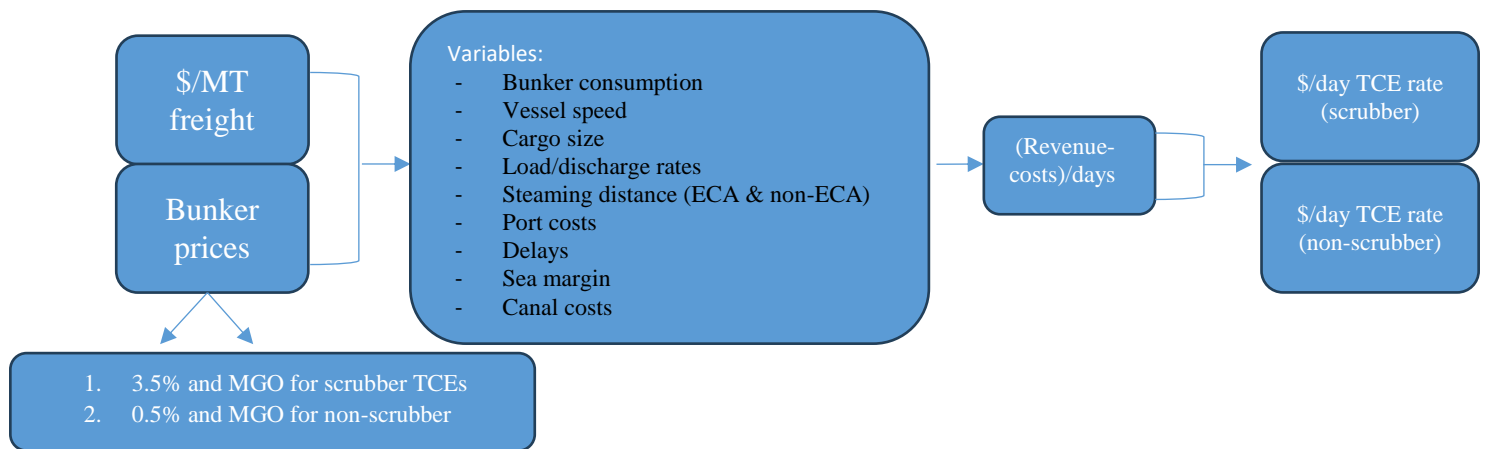


Figure 1 Platts TCE Calculation.
Source: (S&P Global Platts, 2020)

The following practical examples illustrate the TCE calculation.

➤ Supramax vessel
Cargo: 50,000 MT bulk cargo
Freight pmt: Usd 19.00 /MT
Voyage Duration: 40 days
Freight earnings: USD 950,000.00
Less Brokerage commission 1.25% * \$950,000= USD 11,875.00
Less Voyage Costs: USD 285,000.00
Voyage income: USD 653,125.00
TCE: USD 16,328,13 / day

➤ Handysize vessel:
Cargo: 28,000 MT bulk cargo
Freight pmt: Usd 20.00 / MT
Voyage Duration: 28 days

Freight earnings: USD 560,000.00
Less Brokerage commission $1.25\% * \$560,000 =$ USD 7,000.00
Less Voyage Costs: USD 165,000.00
Voyage income: USD 388,000.00
TCE: USD 13,857.14 / day

(heisenbergshipping, 2024)

These examples demonstrate how TCE facilitates the comparison of the profitability of disparate voyages across routes and market conditions, thereby enabling shipowners to optimize their operations and benchmarking during decision-making.

3. Methodology and Results

The methodology of this study integrates multiple research approaches to achieve a comprehensive evaluation of voyage estimation in dry bulk shipping. Calculations use real-world market conditions to provide an objective comparison of vessel profitability. By utilizing a quantitative research approach, this study systematically assesses the revenue and cost elements associated with vessel deployment, enabling a comparative analysis of two selected vessels for a specific cargo and route. Specifically, the study examines the selection of two Ultramax bulk carriers, one scrubber-equipped and one non-scrubber equipped, performing the same voyage under identical conditions. The objective is to assess the impact of scrubber technology on TCE optimization, voyage profitability and operational efficiency.

The multifaceted approach used in this study, includes comparative analysis, documentary data review and qualitative insights. It applies voyage estimation techniques to evaluate and compare economic and operational factors that influence voyage costs and revenues. An extensive review of the existing literature is conducted to examine previous studies on voyage estimation, fuel efficiency and vessel selection in bulk shipping. The methodology is structured to ensure accuracy in estimating the total voyage duration, revenue generation and associated costs. The technological advancements employed in this study, including routing tools and fuel consumption models, contribute to the enhanced precision of the findings.

Given the volatility of market conditions, particularly in freight rates, bunker prices and port charges, the study adopts a data-driven approach to provide reliable TCE calculations. A critical aspect of the methodology is the evaluation of key financial and environmental factors that affect vessel performance. The presence of a scrubber allows vessels to consume High Sulfur Fuel Oil (HSFO), which is typically more economical than Very Low Sulfur Fuel Oil (VLSFO), the only compliant fuel for non-scrubber vessels under IMO 2020 regulations. (ICS, 2019) By incorporating bunker price differentials and operational expenses into the voyage estimation, the study provides a detailed cost-benefit analysis of scrubber adoption.

In addition to economic and operational considerations, the study examines regulatory and environmental factors, in particular the impact of scrubbers influences on emissions compliance and long-term adjustments based on evolving market conditions and new industry data. (IMO, 2021)

The multiple research techniques result in a systematic and in-depth analysis and evaluation of all steps in the vessel selection process and provide practical insights for optimizing TCE in dry bulk shipping.

3.1. Research design and Data Collection

The research follows a comparative voyage estimation approach, which analyzes the performance of two vessels under identical conditions to identify cost and operational differences. This design provides an objective assessment of scrubber-equipped versus non-scrubber vessel performance in real-world shipping conditions. (KUSHWAHA et al., 2024)

The research process begins with data collection, which integrates both primary and secondary data sources to ensure an accurate and detailed evaluation of the voyage estimation in the dry bulk shipping sector.

Primary data includes real-world voyage estimation data, fuel consumption records and port fees structures. The study gathers information on bunker prices and fuel consumption rates for scrubber-equipped vessels versus those without, sourced from industry reports and operational data. It also includes voyage distance calculations and estimated voyage duration based on actual shipping routes obtained from navigation systems and voyage logs. Additionally, port-related costs and fuel supply availability at various ports are

collected from port authority publications and shipping company records. All of this primary data is sourced from reputable industry sources, market intelligence platforms and operational reports from shipping company, ensuring the reliability and relevance of the information.

Another critical component of primary data collection involves gathering relevant information on vessel specifications, sourced from charter agreements and operational records within the shipping company. Vessel specifications, including speed, fuel consumption and deadweight capacity are incorporated into the analysis, as they directly influence the voyage performance.

Secondary data is collected from academic literature, industry reports and regulatory documents to provide context and support for the primary data. Key sources include IMO regulations (ICS, 2019) detailing emission compliance standards and guidelines for scrubber usage. These are considered essential for understanding the regulatory environment affecting vessel operations. Freight market reports and bunkers price trends from organizations such as BIMCO and Clarksons Research offer insights into market dynamics and fuel prices that impact the voyage profitability. Voyage estimation models used in the shipping industry furnish frameworks and methodologies for precise voyage cost estimation. Environmental impact studies, which evaluate the effect of scrubber technology on emissions and marine ecosystems contribute to a holistic understanding of the environmental implications of different fuel strategies. (IMO, 2023a)

Following data collection, the voyage estimation process is undertaken. This includes calculating total voyage duration, which accounts for ballast, laden and port/idle time and loading and discharging rates. Revenue is then estimated by multiplying the agreed freight rate by the cargo volume. Subsequently, total voyage costs are determined, including fuel consumption, port charges and other operational expenses. The final step in the process is computing TCE using the industry-standard formula:

$$\text{TCE} = \frac{(\text{Freight revenue} - \text{Voyage costs})}{\text{Voyage duration}} \quad (\text{S\&P Global Platts, 2020})$$

To enhance the robustness of vessel selection, a sensitivity analysis is conducted. This analysis examines how changes in key market variables affect TCE values. By evaluating these fluctuations, the study ensures that vessel selection remains optimized under varying economic conditions.

This study employs Microsoft Excel as the primary tool for the voyage estimation. Excel provides a structured and flexible platform for organizing input variables, performing calculations and analyzing results. The software is used to create formula-based models that allow for efficient revenue and cost computations, along with scenario adjustments to evaluate different market conditions.

Scenario analysis plays a critical role in assessing vessel performance under various external conditions. By modifying inputs related with freight rates and fuel costs, multiple simulations can be conducted to examine how different economic scenarios influence vessel profitability. In addition, data validation techniques are applied to ensure input accuracy, minimizing errors in estimation and improving the reliability of results. (Burke & Kendall, 2014)

3.2. Assumptions and Limitations

Several assumptions are made to streamline the analysis. Firstly, it is assumed that freight rates remain constant for the duration of the selected voyage. While fluctuations are common in shipping market, this assumption allows for a controlled comparison of vessel profitability. Secondly, voyage duration is estimated using relevant software and digital tools, where all necessary input parameters are provided. The vessel speed is assumed to be eco-speed to reflect fuel-efficient operations. While real-world variations, such as weather disruptions and port congestion, may affect the actual voyage times, these estimates provide a standardized basis for comparison.

Port and canal dues are considered fixed at published tariff rates, although these costs may be subject to policy changes or special surcharges. In order to ensure consistency, the study relies on publicly available data at the time of analysis. The methodology, further assumes that both vessels under consideration are available for charter and do not face scheduling conflicts or maintenance issues that could prevent deployment.

Despite the structured methodology, there are limitations that must be acknowledged. Market fluctuations beyond the selected timeframe are not accounted for, meaning that significant changes in freight rates or fuel prices could alter the actual voyage profitability. To address this, assumptions are made regarding bunker price fluctuations based on the port of delivery and their impact on the TCE is assessed.

Finally, this study focuses only on voyage charters and does not extend to time charter arrangements, which involve different financial and operational considerations.

3.3 Understanding Voyage estimation

Voyage estimation is a detailed analysis of costs and revenue expectations to determine the profitability of a particular voyage. Shipowners and charterers rely on a combination of historical data, industry experience and port agent report to refine their estimates and optimize vessel deployment.

Modern voyage estimation practices leverage software solutions. This integration ensures consistency, accuracy and efficiency when evaluating alternative charter options. A well-executed voyage estimation enables a systematic and comparative analysis between projected and actual voyage performance.

A standard voyage estimation framework incorporates a variety of elements, including vessel information such as the vessel's name and specifications. It also considers the voyage route, detailing the loading and discharge ports, any intermediate stops and the vessel's positioning after the voyage. Cargo details are another key component, including the cargo type, its stowage factor, weight and volume. The freight rate outlines the payment terms for the transporting the cargo. Voyage costs consist of fuel consumption, port charges, canal dues and other operational expenses. The financial assessment is commonly conducted in Usd currency to maintain uniformity in calculations and simplify cost-profit evaluation and comparison.

The process begins with the collection of essential data, including cargo details, vessel specifications and route information. Cargo type, stowage factor, loading and discharging ports, port restrictions and expected congestions must all be taken into account, as well as do laycan dates which determine the vessel's arrival time. Fuel prices at various ports along the route also play an important role since bunker costs are a significant part of the voyage expenses. Equally important in determining the feasibility of the voyage are the vessel's technical specifications, including deadweight capacity, draft, speed and consumption rates.

Once the data has been collected, the voyage-related costs are calculated, starting with bunker costs. The selected route has a considerable impact on vessel's fuel consumption, with factors such as distance, vessel speed and available refueling points influencing the

overall voyage cost. Routes that pass through major canals, like the Suez or Panama canals, require the payment of additional tolls, which need to be factored into the cost analysis. External conditions, such as weather forecasts, ice formations, piracy risks and port congestion, also affect the route selection and voyage planning. The total voyage time is estimated based on distance and vessel speed, allowing an accurate fuel consumption to be calculated. This consumption is then multiplied by the current bunker price to determine the total fuel cost.

Port-related costs are another critical component, as the duration of a vessel's stay in port depends on loading and discharging rates, berth availability and potential delays. Cargo handling is subject to specific terms and conditions, for example whether loading and unloading operations include or exclude weekends and public holidays, which affects the overall laytime. Fuel consumption during port calls must also be considered, as vessels continue to consume bunkers for auxiliary engines and on-board systems while waiting or handling cargo.

The estimation of revenue is derived through the calculation of maximum cargo intake, with the agreed freight rate per metric ton applied as a multiplier. Deductions are made for both broker and address commissions charged by the cargo owner, with the gross freight revenue thus calculated. Voyage-related expenses are then deducted from the gross revenue to determine the net revenue. This value is then divided by the total number of voyage days, including laden and ballast legs, to determine the TCE. The TCE standardizes voyage profitability, thus allowing for direct comparisons between different cargoes, vessels and routes.

Given the considerable number of dynamic variables involved in voyage calculations, even minor adjustments in bunker prices, port fees or cargo handling times can have a significant impact on profitability. In order to improve the accuracy and efficiency of such calculations, operators frequently utilize specialized software that provides real-time updates on bunker prices, sea routes, port conditions and congestion levels. These tools simplify the decision-making processes by automating calculations and reducing manual effort.

The capacity to evaluate voyage costs, expected revenues and route conditions with precision enables chartering managers and ship-owners to select the most profitable cargo and vessel combinations, thus optimizing these factors. This, in turn, enhances operational

efficiency, reduces risk and maximizes returns in a constantly shifting market. (Omholt-Jensen, 2024)

3.4 Methodology and Computational Process

A precise voyage calculation is imperative for converting the collected data into actionable insights, thereby enabling informed decision-making in vessel selection and operational planning. The voyage calculation process accounts for critical cost components, including but not limited to fuel consumption, port calls, canal transits and time at sea, to provide a comprehensive financial forecast.

The selection of a vessel plays a fundamental role in shaping the cost and revenue structure of a voyage, thereby influencing overall profitability. Cargo-specific factors, including type and quantity, have a direct impact on freight revenues and handling costs. (Özdemir & Guneroglu, 2018) Similarly, voyage-specific constraints such as port restrictions, distance and bunkering options determine the fuel consumption and operational efficiency. (Song & Panayides, 2021) Vessel characteristics, particularly size, age, speed and technological features (scrubber vs. non-scrubber), also affect bunker consumption and maintenance costs. Economic variables, including freight rates, bunker prices and potential demurrage or dispatch, affect the vessel's TCE performance.

By incorporating these selection criteria into voyage calculations, this chapter provides a structured methodology and the fundamental formulas to evaluate voyage profitability, assess cost efficiency and compare vessels configurations. This analytical process ensures that decision-making is based on quantifiable data and enables the identification of the most profitable vessel for a given cargo and trade route.

1. Vessel specifications

Vessel Name and IMO number: The designated name assigned to a vessel for identification, tracking and communication purposes within the maritime industry. It is registered with maritime authorities and used in operational records, charter agreements and fleet management. The IMO number is a unique seven-digit identifier assigned to each vessel, ensuring global recognition and regulatory compliance. Unlike the vessel name, which can change over time, the IMO number remains constant throughout the vessel's

lifetime, facilitating accurate vessel tracking, safety regulations and legal documentation. (Ma et al., 2023)

Vessel Type: The classification of a ship based on its design and cargo type. Common vessel types include Bulk Carriers for dry bulk cargo, Tankers for liquid cargo, Container ships for containerized goods and Ro-Ro for wheeled cargo. ('UNCTAD', 2023)

Deadweight Tonnage (DWAT): The total carrying capacity of a vessel, measured in metric tons, including cargo, fuel, water, provisions and crew and other consumables. It represents the difference between the vessel's loaded and light displacement, indicating the maximum load without exceeding safety limits. When a vessel operates in areas with draft restrictions, the maximum load it can carry is limited by the allowable draft. However, if the restriction is given in freshwater (FW), it must be adjusted for seawater (SW) conditions, as vessels float higher in denser seawater. This adjustment is necessary to accurately determine the actual vessel's DWT when it enters seawater. Here are the formulas used for adjusting the vessel's DWT due to draft restrictions considering the impact of water density differences between FW and SW:

$$SSW \text{ Equivalent Draft} = \frac{FW \text{ Draft Limitation}}{1.025}$$

- Freshwater Draft Limitation (m) is the maximum allowable draft at a restricted location in freshwater. This is the depth to which the vessel can be submerged while loading cargo in freshwater.
- 1.025 is the standard density ratio of seawater to freshwater. Seawater has a density of 1.025t/m³, while freshwater has a density of 1.000t/m³.
- SSW Equivalent Draft (m) is the adjusted draft limit in seawater.

$$Draft \text{ Reduction} = SSW \text{ Draft} - SSW \text{ Equivalent Draft}$$

- SSW Draft (m): The vessel's draft when fully loaded in seawater under summer conditions. This represents the maximum draft the vessel is designed to operate at in open sea conditions.
- Draft Reduction (m): The amount by which the vessel's draft must be reduced to comply with the FW draft restriction. This indicates how much less cargo the vessel can carry due to the limitation.

$$\text{Weight Loss} = \text{Draft Reduction} \times \text{TPC}$$

- TPC (Tons per centimeter immersion) (mt/cm): Vessel's specific value that represents the weight needed to change the draft by 1cm. It depends on the vessel's hull shape and size. A higher TPC means the vessel requires more weight to submerge further.
- Weight Loss (mt): The total reduction in DWT caused by the draft limitation. This is the amount of cargo or ballast that must be deducted from the vessel's capacity to comply with the draft restriction.

$$\text{New DWT} = \text{Original DWT} - \text{Weight Loss}$$

- Original DWT or DWAT (mt): The vessel's maximum DWT capacity in unrestricted conditions (e.g. when loading up to its full draft in seawater).
- New DWT (mt): The adjusted DWT capacity under restricted draft conditions. This is the actual maximum amount of cargo and other load the vessel can carry complying with the draft limitation.

Constants: The fixed weights on a vessel that are not related to cargo, including permanent equipment, machinery and other onboard items necessary for operations. These weights remain unchanged throughout the voyage and are deducted from the vessel's DWAT to determine the available cargo capacity.

Bunkers: The fuel stored onboard a vessel, used to power main engines and auxiliary systems throughout the voyage. This includes Fuel oil (F/O) and Marine Gas Oil (M.G.O.). The quantity of bunkers varies depending on the voyage duration and operational requirements.

Ballast and Fresh water: The water stored on a vessel for stability and operational needs. Ballast water is taken on or discharged to maintain the vessel's balance, draft and structural integrity, especially when sailing without cargo. Fresh water is carried for crew consumption, sanitation and machinery cooling. The total weight of ballast and fresh water affects the vessel's cargo capacity and overall fuel efficiency.

Deadweight Cargo Capacity (DWCC): The maximum weight of cargo a vessel can carry after accounting for fixed weights such as constants, bunkers, ballast and fresh water. It is calculating by deducting these elements from the vessel's total deadweight tonnage

(DWAT). It provides an accurate measure of the vessel's net cargo-carrying capacity. (Rahaman, 2018)

$$DWCC = DWAT - Constants - Bunkers - Ballast \& Fresh Water$$

2. Speed and Consumptions

When estimating voyages and calculating bunker consumption, several key parameters affect fuel consumption in different operating conditions. These parameters are the ballast, laden, load port and discharge port bunker consumption rates.

Ballast speed is the ship's sailing speed without cargo, while laden speed is the ship's speed when it is fully loaded. These speeds expressed in knots (KN) have a direct impact on fuel consumption and there are consumption rates for each type of bunkers, fuel oil (FO) or marine gas oil (MGO). When the vessel is in port for loading, discharging or bunkering supply, the port fuel consumption rate considers the daily fuel consumption, which increases when cranes and other cargo handling equipment are in operation. In addition, when the vessel is idle, the idle fuel consumption rate is considered, which reflects the minimum daily fuel required for essential systems and crew operations.

In regions classified as Emission Control Areas (ECAs) under Marpol Annex VI, environmental regulations require the utilization of very low sulfur oil (VLSFO) with a sulfur content of $\leq 0.10\%$, or marine gas oil (MGO). (IMO, 2023b). The ECA ballast/laden fuel consumption rate denotes the vessel's fuel consumption while sailing within these zones. Conversely, when sailing outside ECAs, vessels may use higher sulfur fuels, which will affect the overall bunker costs.

3. Fuel prices

The price of HSFO, VLSFO and MGO is measured in US dollars per metric ton. (US\$/MT)

4. Voyage

- A Voyage number is a unique identifier that is assigned to a specific voyage of a vessel and allows for accurate tracking and communication within the maritime industry. (Portcast, n.d.)

- Date refers to the voyage commencement date, which is the specific date on which the voyage begins.
- Cargo refers to the specific type of commodities being transported from one port to another other.
- The quantity represents the total cargo being transported, usually expressed in metric tons (MT).

$$Quantity = DWCC$$

The amount of cargo is calculated by the above formula, which corresponds to the DWCC of the vessel. DWCC is the maximum amount of cargo a vessel can carry (capacity).

- Freight Rate is the charge applied by a carrier for the transportation of the cargo from one location to another. This rate is commonly denoted as a cost per unit of weight or volume, such as Us\$/MT, and defines the total cost required for shipping the cargo.
- Commissions are fees associated with the arrangement and facilitation of cargo transportation, typically calculated as a percentage of the freight rate. These include the address commission, a fee paid by the shipowner to the charter, often ranging from 1,25% to 5% of the gross freight rate and the brokerage commission, usually about 1,25% of the gross freight, compensating the shipbroker for their services in negotiating and securing the charter agreement. (HandyBulk, n.d.)

5. Voyage duration

A voyage consists of several segments, called legs, each representing a specific part of the voyage between two or more points. The departure point, “from”, for each leg is referred to as the start point, while the destination port marks the arrival point. The distance of each leg is measured in nautical miles, which are categorized into miles within ECAs and miles outside ECAs based on regulatory requirements. In addition, the operating condition of the vessel is specified as either ballast (B) or laden (L).

The number of steaming days in Non ECA Zone is calculated as follow:

$$BDaysNonECA_L = \frac{MilesNonECA_L}{24 \times SpeedB}$$

$$LDaysNonECA_L = \frac{MilesNonECA_L}{24 \times SpeedL}$$

The total miles for a voyage are the cumulative sum of the miles for all legs, while the total steaming days are the total number of sailing days for the whole voyage.

$$Total\ Miles = \sum_{L=1}^3 MilesB + MilesL$$

$$Total\ SteamingDays = \sum_{L=1}^3 Bdays + Ldays$$

6. Estimate port days

Estimating port days involves analyzing key port details, including load and discharge rates, estimates of arrivals and departures, and the impact of holidays or non-working days.

The load rate is the speed at which cargo is loaded, while the discharge rate is the unloading speed, both commonly expresses in unit per day.

The arrival date indicates the expected arrival of the vessel at designated port. The days in port are calculated by dividing the total cargo by the corresponding load or discharging rate, depending on the operation being performed.

$$DaysinPort_j = \begin{cases} \frac{CargoQuantity}{Load\ Rate} \\ \frac{CargoQuantity}{Discharge\ Rate} \end{cases}$$

To account for possible variations, a margin is included that represents a float between the estimated arrival and departure dates. This margin is derived by subtracting the sum of the arrival date and port stay duration from the estimated departure date. Since SHINC, (Sundays and Holidays included), is applied to simplify the calculations, non-working days are not considered, meaning operations proceed every day without interruption.

$$Margin_j = EstimatedDepartureDate_j - (ArrivalDate_j + DaysinPort_j)$$

The estimated departure date is then determined by adding the arrival date and the total number of days in port.

$$DepartureDate_j = ArrivalDate_j + DaysinPort_j + Margin_j$$

Since SHINC applies, no additional adjustments are required for non-working days, as loading and discharging occur continuously, including weekends and holidays.

The total days in ports are calculated by adding the estimated time in ports and the margin for all calls.

$$Total\ Days\ in\ Ports = \sum_{j=1}^3 DaysinPort_j + Margin_j$$

7. Fuel consumptions and costs

For each voyage leg FO consumption is calculated by multiplying the daily fuel oil consumption rate by the number of ballast or laden days. Similarly, MGO consumption is determined by multiplying the daily marine gas oil consumption rate by the number of ballast or laden days.

$$FO\ Consumption = \begin{cases} BConsumption\ Rate \times BDaysNonECA\ or\ ECA \\ LConsumption\ Rate \times LDaysNonECA\ or\ ECA \end{cases}$$

$$MGO\ Consumption = \begin{cases} BConsumption\ Rate \times BDaysNonECA\ or\ ECA \\ LConsumption\ Rate \times LDaysNonECA\ or\ ECA \end{cases}$$

The FO cost for each leg is obtained by multiplying the total fuel oil consumed (mt) by the price per MT, while the MGO cost is calculated by multiplying the marine gas oil consumed by its respective price per MT.

$$FO\ Cost = FO\ Consumption \times FO\ Price$$

$$MGO\ Cost = MGO\ Consumption \times MGO\ Price$$

Port Fuel Consumptions and Costs:

Fuel consumption continues to accrue while the vessel is in port. Therefore, FO consumption in port is calculated by multiplying the number of days in port by the vessel's daily FO consumption rate and the MGO consumption in port is determined in a similar manner by using the daily MGO consumption rate.

$$FO\ Port\ Consumption = Port\ Consumption\ Rate \times (DaysinPort_j + Margin_j)$$

$$MGO\ Port\ Consumption = Port\ Consumption\ Rate \times (DaysinPort_j + Margin_j)$$

The respective consumption amounts are then multiplied by the current prices per mt to calculate the associated costs.

$$FO\ Port\ Cost = FO\ Port\ Consumption \times FO\ Price$$

$$MGO\ Port\ Cost = MGO\ Port\ Consumption \times MGO\ Price$$

Furthermore, idle time, when the vessel is not in active operation, also contributes to fuel consumption. The FO consumption during idle days is calculated by multiplying the number of idle days by the daily FO consumption rate and idle MGO consumption is similarly calculated.

$$FO\ Idle\ Consumption = FO\ Idle\ Consumption\ Rate \times IdleDays$$

$$MGO\ Idle\ Consumption = MGO\ Idle\ Consumption\ Rate \times IdleDays$$

The respective consumption amounts are then multiplied by the current prices per MT to determine the costs associated with these idle periods.

$$FO\ Idle\ Cost = FO\ Idle\ Consumption \times FO\ Price$$

$$MGO\ Idle\ Cost = MGO\ Idle\ Consumption \times MGO\ Price$$

8. Total Costs & Total Voyage days

Costs consist of several categories, including operational expenditures (OPEX), which refer to the recurring operational costs associated with vessel management.

Capital costs include expenses such as insurance, covering various policies like P&I, FD&D and H&M, and loan repayments with respect to the financing of vessel. The total cost of capital is derived by adding loans and insurance.

$$\text{Total Capital Cost} = \text{Loan} + \text{Insurance}$$

The aforementioned costs are applicable when operating an owned vessel. However, when a vessel is chartered on a time charter (TC), the charterer becomes the disponent owner. Consequently, instead of directly covering OPEX and capital expenses, the charterer pays a fixed daily hire rate to the vessel owner.

Voyage costs include a variety of expenses incurred during a vessel's voyage. These include loading and discharging port fees, bunkering call port and agent fees, canal transit fees and the overall fuel consumption costs during the voyage.

$$FO \text{ Total Costs} = \sum_{L=1}^3 FO\text{Cost}_L \sum_{J=1}^3 FO\text{Port Cost}_J + FOBunkering \text{ Cost} + FO\text{Idle Cost}$$

$$MGO \text{ Total Costs} = \sum_{L=1}^3 MGO\text{Cost}_L \sum_{J=1}^3 MGO\text{Port Cost}_J + MGO\text{Bunkering Cost} \\ + MGO \text{ Idle Cost}$$

$$\text{Total Fuel Costs} = FO \text{ Total Costs} + MGO \text{ Total Costs}$$

Additional expenses may include extra voyage insurance, fees for pilotage services during port entries and exits and other miscellaneous expenses that are not covered in specific categories. A critical additional cost is the dispatch, which is the compensation paid by the shipowner to the charterer when loading or discharging operations are completed within a shorter time than the agreed laytime. It is the opposite of demurrage, where the charterer pays the owner for exceeding laytime. (Aspragkathou, 2007)

The total cost of the voyage is calculated by aggregating all these expenses.

$$\begin{aligned} TotalVoyageCost = & LoadPortCosts + DischargePortCosts + \\ & + CanalDues + TotalBunkersCost + \\ & ExtraInsurance + Pilotage + Despatch + Miscellaneous \end{aligned}$$

To determine all the total voyage time, all time components that refer to the below formula, are added together.

$$TotalVoyageDays = TotalSteamingDays + TotalDaysinPort + IdleDays + CanalDays$$

9. Revenues and Returns

In maritime operations, revenues and returns are pivotal metrics encompassing diverse income sources and profitability measures. Gross freight signifies the total income from transporting cargo, calculated by multiplying the cargo quantity by the agreed freight rate.

$$Gross\ Freight = Freight\ Rate \times Quantity$$

Demurrage is a fee paid by the charterer to the shipowner when loading or discharging operations exceed the agreed laytime. It serves as compensation for the delay, covering the additional time the vessel remains in port beyond the stipulated period. (Kim, 2022)

Extra income includes additional earnings during the voyage, such as ballast bonus, holds cleaning lumpsum amount or any special compensation agreements.

The gross income is the sum of gross freight, demurrage and extra income. After deducting commissions and applicable taxes from the gross revenue, the resulting net revenue represents the actual voyage earnings.

$$Gross\ Income = Gross\ Freight + Demurrage + Extra\ Income$$

$$Net\ Revenue = Gross\ Income - Commission - Freight\ Tax$$

In order to assess the voyage profitability, the voyage surplus is determined by deducting the total voyage costs from the net revenues and shows the remaining revenues after all voyage-related costs have been covered.

$$\text{Voyage Surplus} = \text{Net Revenue} - \text{Total Voyage Costs}$$

The TCE is an industry standard measure of a vessel's average daily revenue performance. It is calculated by dividing the voyage surplus by the total voyage time in days, providing a normalized daily revenue figure that allows performance comparisons between different voyages and vessel types.

Based on the above voyage estimation calculations (Pagonis & Pentheroudakis, 2019) and (Argyarakis, 2024), the formula for calculating TCE is:

$$TCE = \frac{\text{Voyage Surplus}}{\text{Total Voyage Days}}$$

10. Charter-In analysis

Following the calculation of the TCE, a comprehensive examination and analysis of the chartering process is essential. This analysis is focusing on the factors that influence the decision to charter a vessel from a third party. In instances where a shipowner does not have an available vessel to fulfill a specific cargo contract, they may charter a vessel from another company to execute the cargo contract and generate a profit. This analysis evaluates revenue estimates, projected costs, net income calculations and profit margin of the disponent owner responsible for managing the chartered vessel. (Plomaritou & Papadopoulos, 2018)

Charter in:

A charter-in occurs when a disponent owner secures a cargo contract but lacks an available vessel to execute the voyage. To fulfill the agreement and maintain profitability, they charter a vessel from the market under a pre-agreed hire arrangement.

The net freight income signifies the revenue derived from the agreed freight rate.

$$\text{Net Freight Income} = \text{Net Revenue}$$

In instances where a vessel is chartered under a time charter-in agreement, the hire freight rate constitutes the per metric ton (MT) rate agreed upon with the vessel owner for the transportation of cargo.

$$\text{Hire Freight Rate} = \frac{\text{Hire Total}}{\text{Quantity}}$$

The hire total is the total amount payable to the shipowner, calculated by multiplying the hire rate by the cargo quantity transported.

$$\text{Hire Total} = \text{Hire Freight Rate} \times \text{Quantity}$$

The hire total expenses include all the costs associated with the charter-in, including vessel hire and voyage-related expenses.

$$\text{Hire Total Expenses} = \text{Hire Total} + \text{Total Voyage Expenses}$$

After deducting these total expenses from the net freight income, the remaining profit is referred as net income.

$$\text{Net Income} = \text{Net Freight Income} - \text{Hire Total Expenses}$$

The profit margin indicates the expected percentage of profit that the disponent owner seeks to obtain.

$$\text{Profit Margin} = \frac{\text{Net Income}}{\text{Net Freight Income}}$$

3.5 Voyage estimation accuracy in decision-making.

The importance of using Excel for voyage estimation lies in its flexibility, transparency and accessibility, allowing for real-time scenario analysis, cost breakdowns and sensitivity analysis that are consistent with industry standards. The voyage estimation process in this study integrates real data from a shipping company, ensuring that vessel specifications are accurately reflected. Route distances and nautical miles are sourced from industry recognized voyage planning tools (*NETPAS DISTANCE*, n.d.), ensuring accurate calculations for ballast and laden legs. Leveraging Excel's formulas and financial model capabilities, the estimation process reflects best practices in the shipping industry while allowing for scenario adjustments based on market conditions. In addition, the manual

input and validation of assumptions provides a structured yet adaptable framework that supports comparative vessel selection and TCE optimization analysis.

The accuracy of the voyage estimation is further enhanced by the integration of bunker fuel prices from S&P Global Platts, a widely recognized industry benchmark for real-time bunker cost assessments. This ensures that fuel price fluctuations and their direct impact on voyage profitability are accurately accounted for. Similarly, port charges for loading, discharging and bunkering are based on historical data and agent quotations for vessels of similar DWT and port stay duration, providing a realistic basis for cost estimation that is consistent with industry norms. Moreover, the incorporation of industry-standard voyage estimation models ensures that the financial and operational results align with actual shipping practices, enhancing the validity of the TCE optimization analysis. This methodology ensures that the results are not only data-driven, but also replicable and applicable to real-world dry bulk shipping operations, contributing to a comprehensive and decision-oriented approach to vessel deployment and cost optimization.

4. Data Analysis

4.1 Cost and Revenue Breakdown

This section presents a thorough analysis of the earnings generated and the costs incurred during the voyage. The financial outcome of the voyage is determined by the balance between freight earnings and voyage expenses. An overview of these components provides a clear understanding of the economic structure of the voyage before proceeding to the comparative analysis in the next section.

The primary source of revenue for both vessels is net freight earnings, which are determined by the cargo volume, the agreed freight rate and the total voyage distance. On this particular voyage, both vessels carried approximately 40,000 mt of soya beans at a freight rate of \$37.00 per metric ton. The table below provides a breakdown of the total net freight earnings for each vessel:

Vessel type	Cargo (mt)	Freight rate Us\$/mt	Total Net Freight (Usd)
Non-Scrubber	40,019	37.00	1,406,667.85
Scrubber-Fitted	40,071	37.00	1,408,495.65

Table 1 Total Net Freight Comparison
Source: Author

The voyage covered a total distance of 7,681 nautical miles (NM), beginning with the ballast leg from Recalada to San Lorenzo, Argentina, (308 NM), where the vessels loaded their cargo. From there they continued their laden voyage to Las Palmas, (4,794 NM), where a bunkering call was scheduled before proceeding to Damietta, Egypt, (2,579 NM), for the cargo discharge. This route is currently classified as part of a Non-ECA zone, meaning that there are no specific sulfur emission restrictions that affect fuel selection. However, in line with upcoming regulatory changes, the Mediterranean will be officially designated as an Emission Control Area, (ECA) from May 1, 2025. This regulatory change will require vessels operating in the region to comply with stricter limits on sulfur emissions. It is expected that this shift will have a significant impact on fuel costs and operational decisions. ('DNV', 2023)

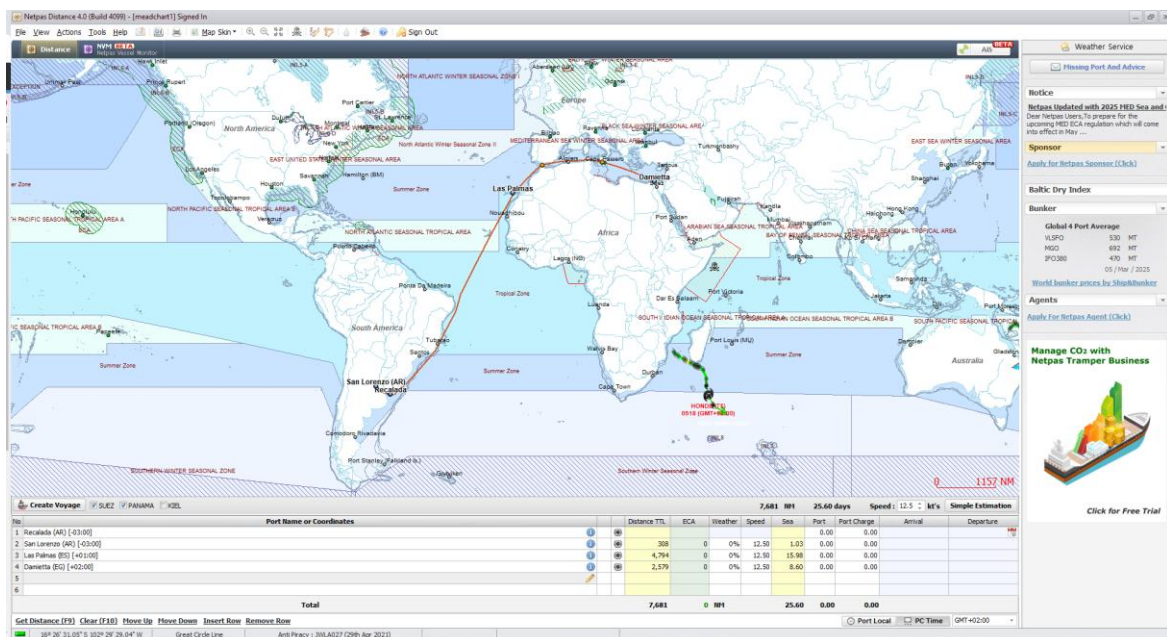


Figure 2 Voyage route.
Source: (NETPAS DISTANCE, n.d.)

While the scrubber-fitted vessel earns a slightly higher net freight compared to the non-scrubber vessel, this increase is attributed to its ability to carry 52 additional MT of cargo. However, this difference is minimal in the overall comparison. The more significant financial impacts arise from cost structure of the voyage, especially in bunker consumption and fuel prices, which have a direct impact on profitability.

The two vessels use different types of fuel with different pricing and consumption characteristics. The non-scrubber vessel uses Very Low Sulfur Fuel Oil (VLSFO), which is required to comply with global sulfur regulations. In contrast, the scrubber-equipped vessel benefits from the ability to burn High Sulfur Fuel Oil (HSFO), which is generally cheaper than VLSFO. In addition, both vessels consumed Low Sulfur Marine Gas Oil (LSMGO) during port operations and for auxiliary engine use. However, the scrubber operation requires additional power, especially during maneuvering and port calls. Port fuel consumption is another factor contributing to total fuel costs. These two bulk carriers are equipped with on-board cranes to facilitate loading and discharging cargo in ports, especially in ports lacking such infrastructure. The use of the cranes result in higher fuel consumption while the vessels are in port.(Iio, 2002)

The difference in fuel prices between HSFO and VLSFO has a direct impact on the total cost of voyage. The non-scrubber vessel relying on VLSFO face higher bunker costs, while the scrubber-fitted vessel achieves cost savings by burning the more economical HSFO.

In addition to fuel consumption, both vessels incur port costs. These costs include loading charges at San Lorenzo, bunkering call fees at Las Palmas and discharging expenses at Damietta. Since, these costs are standardized for the type and size of these two vessels, they do not create any financial differences between them. This means that the variation in total voyage costs is primarily due to fuel selection and consumption patterns rather than port-related expenses.

Beyond the bunker and port expenses, both vessels also incur miscellaneous costs, which include agency fees, documentation expenses and minor operating expenses. These costs remained constant for both vessels and therefore do not affect the overall differences in voyage profitability.

Here is the cost breakdown for each vessel:

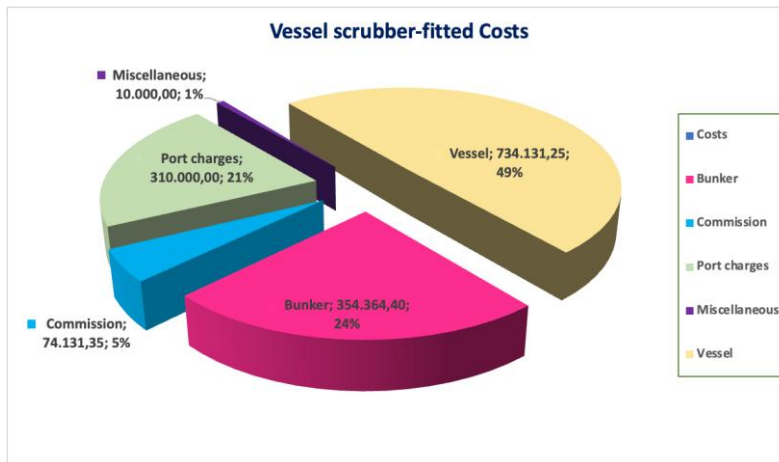


Figure 3 Scrubber-fitted Vessel Costs.
Source: Author

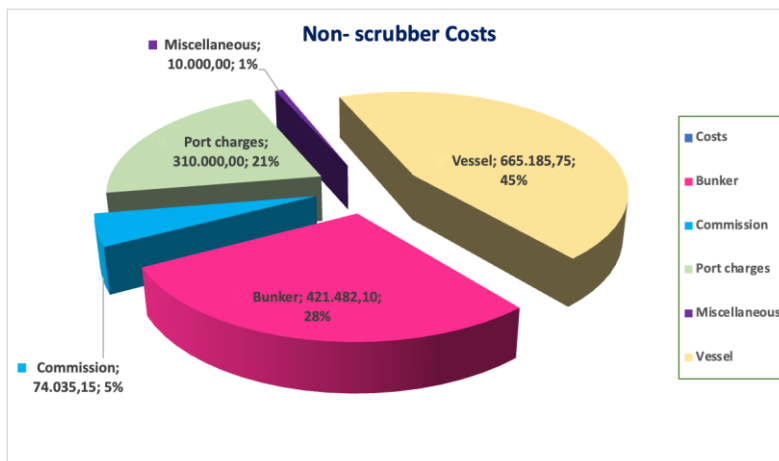


Figure 4 Non-Scrubber Vessel Costs.
Source: Author

4.2 Comparative TCE Analysis: Scrubber-Fitted vs Non-Scrubber Ultramax

The present analysis is based on a voyage estimation performed using an Excel model, which compares the key operational and financial indicators of two vessel types under identical cargo and market conditions. The comparison is constructed on a number of main assumptions including freight rate, fuel prices and vessel speed and consumption. The primary performance indicators examined in this study include Net TCE (\$/day), total voyage duration (days), total bunker costs (\$) and overall profitability (P&L).

Performance metric	Non-scrubber (VLSFO)	Scrubber-fitted (HSFO)	Impact on TCE
Net TCE (\$/day)	\$15,247	\$16,382	Scrubber vessel earns \$1,135/day more
Bunker costs (\$)	\$421,482	\$354,364	Scrubber vessel saves \$67,118 on fuel
Voyage duration (days)	43.63	44.81	Scrubber is 1.18 days slower
Fuel type used	VSLFO (\$575/mt)	HSFO (\$535/MT)	Scrubber burns cheaper fuel
CO ₂	Higher	Lower	Scrubber vessel is more sustainable
P&L (\$/voyage)	\$228,922	\$196,373	Non-scrubber is more profitable

Table 2 Comparative Performance Analysis.

Source: Author

The TCE serves as a benchmark for vessel efficiency, measuring the revenue per day after deducting the voyage-related expenses. The findings of the study indicate that the scrubber-fitted vessel achieves a higher TCE of \$16,382/day, compared to \$15,247.32/day for the non-scrubber vessel. While the scrubber-equipped vessel provides a higher TCE, its profitability is lower than the non-scrubber vessel by approximately 14,22% (\$32,549) due to the higher vessel daily cost, which offset the fuel cost savings.

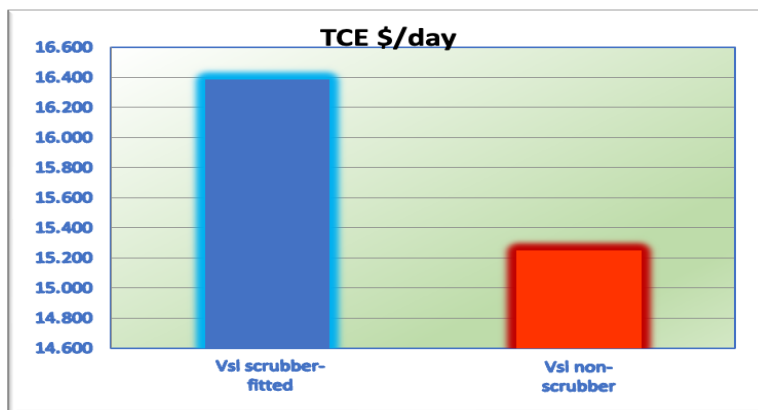


Figure 5 TCE Comparison.

Source: Author

Fuel consumption and bunker price fluctuations have a significant impact on a vessel's operating costs and consequently its TCE. The scrubber-equipped vessel benefits from the ability to burn HSFO (\$535/MT), which is \$40/MT cheaper than VSLFO (\$575/MT), resulting in notable savings in bunker costs. Fuel prices are derived from Platts S&P

Global Commodity Insights, Volume 49/ Issue 17 /January 24, 2025 (Bunkerwire, 2025) at the respective ports.

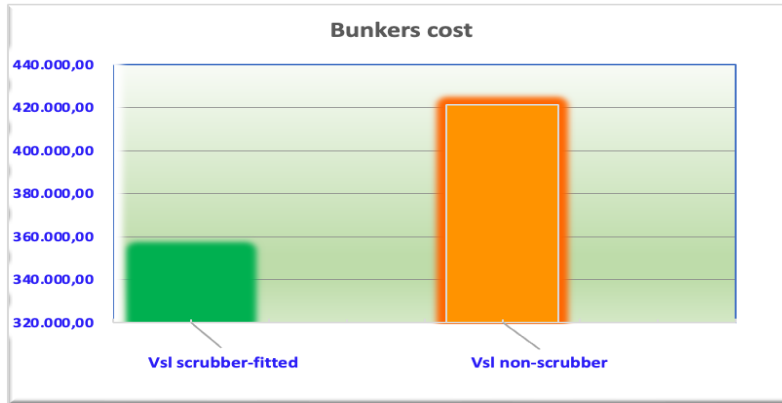


Figure 6 Bunker Cost Comparison.
Source: Author

However, the scrubber-equipped vessel operates at a slower speed, 12 knots laden versus 12.5 knots laden for the non-scrubber vessel, resulting in a 1.18 day longer voyage. While this may not have a significant impact on the overall vessel schedule, it does have an impact on the vessel's turnaround time.

Gross Rate Sensitivity analysis:

The gross rate sensitivity analysis for both vessels shows a direct and linear relationship between gross rate per ton (\$/MT) and TCE (\$/day). With an increase in the gross rate, the net TCE follows a proportional uptrend, confirming that higher freight rates improve vessel profitability.

For the scrubber-fitted vessel, the TCE is \$16,382/day at a gross freight rate of \$37/mt. This trend suggests that rising freight rates lead to a steady increase in TCE, thereby strengthening the economic advantage of scrubber-fitted vessels when fuel cost savings align with favourable freight rates.

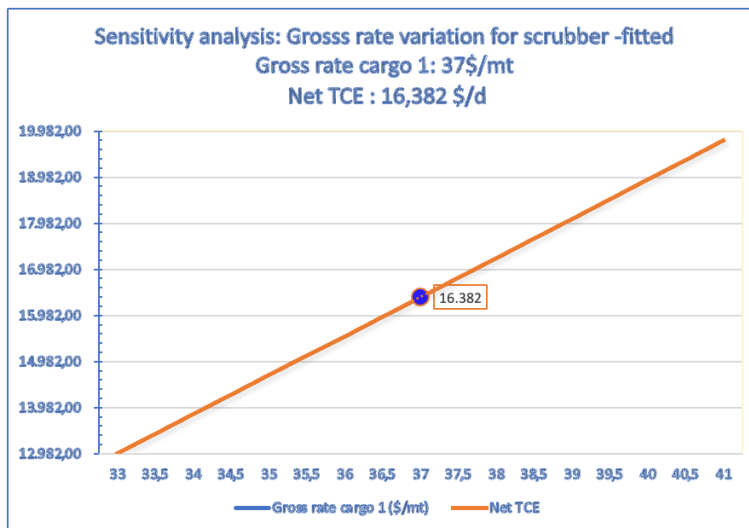


Figure 7 Sensitivity Analysis Scrubber-fitted: Gross rate – Net TCE
Source: Author

In a similar manner, for the non-scrubber vessel, the TCE is \$15,247/day at a gross rate of \$37/mt. Although the TCE for the non-scrubber vessel remains lower than the scrubber vessel, the slope of TCE increase for both vessels is similar as freight rates rise. This indicates that in high freight rate environments, the profitability gap between the two vessel types becomes narrower, potentially making non-scrubber vessels a more viable option.

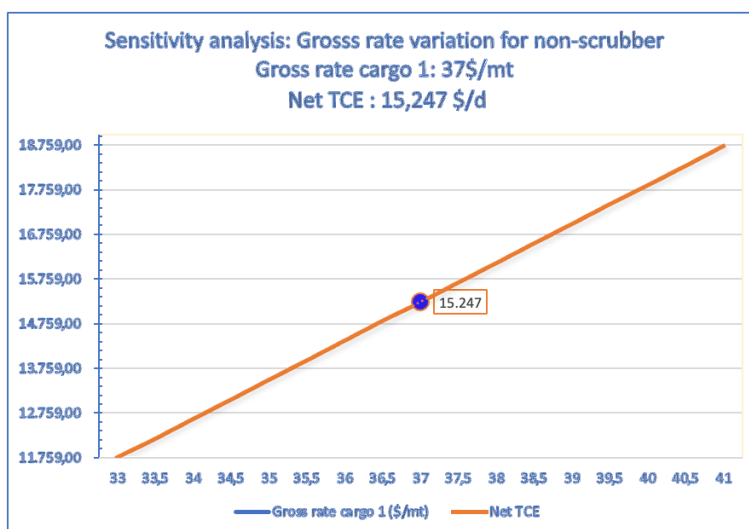


Figure 8 Sensitivity Analysis Non-scrubber: Gross rate – Net TCE.
Source: Author

While, the scrubber-fitted vessel retains a TCE advantage of approximately \$1,135/day, the overall profitability comparison needs to take into account the voyage costs and market

conditions. As freight rates increase, both vessel types benefit in proportion and vessel selection should be based on balancing bunker price spread, charter-in costs and freight market trends.

Bunker cost Sensitivity analysis:

The HSFO bunker cost sensitivity analysis for the scrubber-fitted vessel discloses a negative correlation between HSFO prices and TCE, whereby an increase in HSFO prices from \$455MTt to \$615/MT results in a decrease in TCE from approximately \$17,382/day to \$15,382/day. This outcome confirms that scrubber-fitted vessels benefit from utilizing more economical HSFO. However, their advantage diminishes as HSFO prices increase. The decline in TCE is steady, thereby reinforcing the conclusions that scrubber-equipped vessels remain viable as long as HSFO-VLSFO price spread remains substantial.

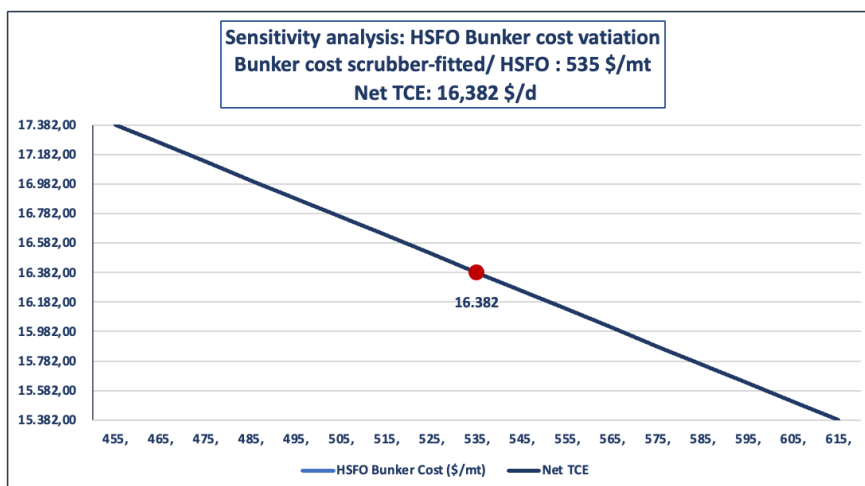


Figure 9 Sensitivity Analysis Scrubber-fitted: HSFO Price – Net TCE

Source: Author

The VLSFO bunker cost sensitivity analysis for the non –scrubber vessel exhibits a linear decline in TCE as VLSFO prices increase. As VLSFO cost increases from \$495/MT to \$655/MT, the TCE drops from approximately \$16,575/day to \$13,000/day. The sharper rate of decline in comparison to the sensitivity of HSFO indicates that non-scrubber vessels are more prone to the price volatility of VSLFO, making them less competitive when VLSFO prices escalate. Conversely, scrubber-fitted vessels maintain a relative advantage when the fuel price gap is significant.

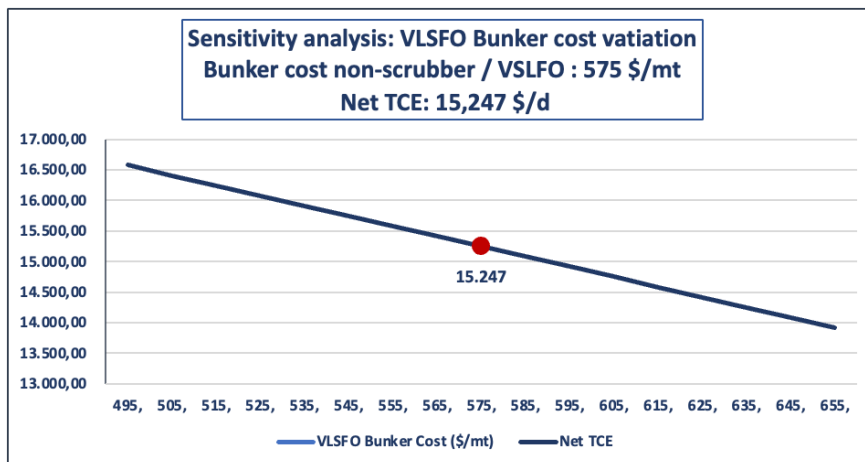


Figure 10 Sensitivity Analysis Non-scrubber: VLSFO Price – Net TCE.
Source: Author

The LSMGO bunker cost sensitivity analysis reveals a gradual decline in TCE for both vessel types, though the impact is marginal. As LSMGO prices increase from \$690/MT to \$850/MT, the TCE decreases slightly for both vessels, but the effect remains less significant compared to the HSFO and VSLFO variations. Since LSMGO is mainly used for auxiliary engines rather than propulsion, its price fluctuations do not critically affect the profitability of the vessels.

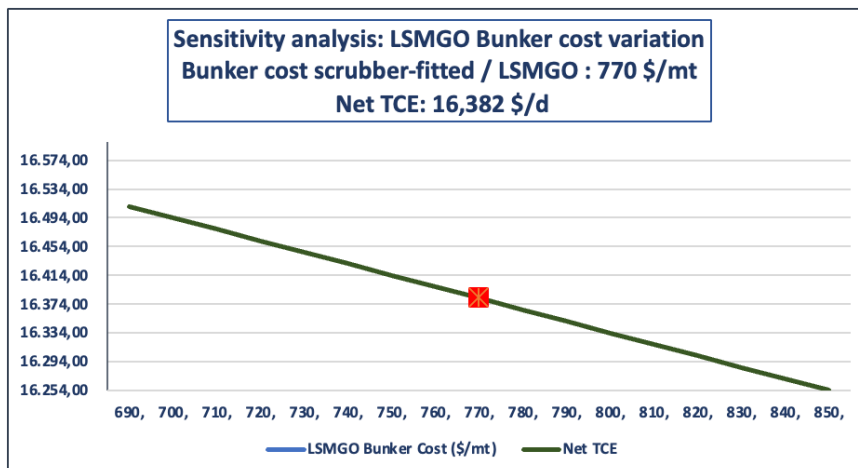


Figure 11 Sensitivity Analysis Scrubber-fitted: LSMGO Price – Net TCE.
Source: Author

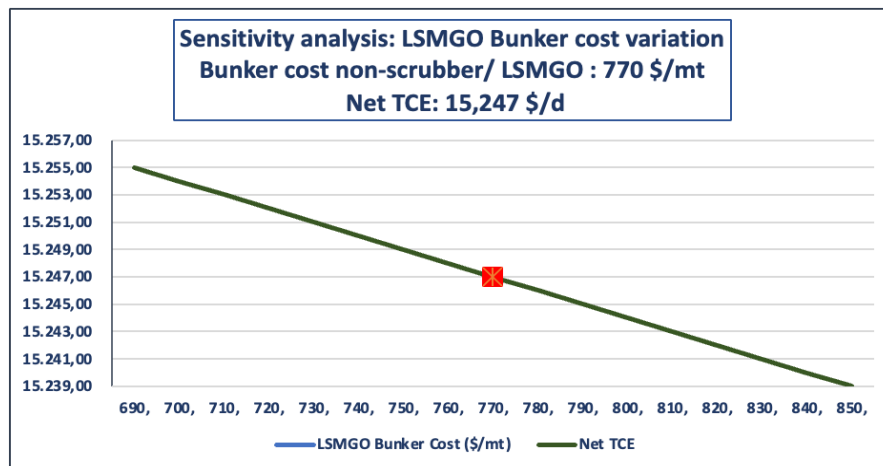


Figure 12 Sensitivity Analysis Non-scrubber: LSMGO Price - Net TCE.
Source: Author

The findings of this study are closely consistent with the research conducted by (Sigalas, 2022) and (Psaraftis, 2019), which reinforces the notion that while technological and regulatory-driven strategies can enhance TCE performance, they do not always translate into higher overall profitability due to the associated capital and operational costs.

(Sigalas, 2022) emphasizes the substantial impact of the IMO 2020 regulation on the dry bulk industry, forcing shipowners to either invest in scrubbers or to bear higher fuel costs by switching to VLSFO. The implementation of a scrubber on a vessel results in cost savings due to the use of HSFO, a more economical fuel option compared to VLSFO. However, this benefit is counterbalanced by a higher charter in daily hire rate (\$12,000/day as opposed to \$10,000/day for the non-scrubber vessel), leading to a marginal reduction in overall profitability. Despite achieving a higher TCE, the higher daily rate of scrubber-equipped vessel than the non-scrubber results in a lower total profit per voyage in comparison to the non-scrubber vessel. This underscores a critical trade-off, while lower fuel costs can enhance efficiency, higher charter in hire expenses can offset these benefits. For shipowners and charterers, the decision-making process entails not only the consideration of fuel savings but also the identification of an optimal balance between charter rates, operating costs and overall profitability when determining the most suitable vessel for a given operation. Furthermore (Sigalas, 2022) research underscores the influence of fuel price volatility and operational strategies such as slow steaming on TCE sensitivity, highlighting that reducing fuel consumption does not necessarily translate into

higher net earnings, particularly when it leads to extended voyage durations or reduces revenue.

In addition, (Psaraftis, 2019) explores the role of green ship technologies in improving energy efficiency, which also relates to the economic and operational trade-offs identified in this study. These technologies have been shown to reduce fuel consumption and thus potentially increase TCE. However, the significant capital investment required for these innovations, reinforcing the idea that increased efficiency does not automatically translate into increased profitability.

As illustrated by the scrubber-equipped vessel in this study, while optimizing TCE through fuel-saving technologies and regulatory compliance strategies is beneficial for operational efficiency, the financial viability of such decisions depends on balancing upfront investments costs, charter in hire rates and overall market conditions. This underscores the importance for shipowners and charterers to undertake a comprehensive evaluation of vessel selection, thereby ensuring that any enhancements in TCE do not result in a reduction in long-term profitability.

5. Conclusions

5.1 Summary of Key Findings

The present study focused on optimizing vessel selection in dry bulk shipping by analyzing TCE under voyage charter. The main findings showed that a comparative analysis of scrubber and non-scrubber vessels showed significant differences in TCE performance depending on bunker prices and market conditions. Sensitivity analysis indicated that fluctuations in fuel prices and changes in freight rates can substantially impact vessel profitability, underscoring the dynamic nature of vessel selection decisions. The comparative analysis showed that in markets with significant HSFO-VSLFO price spreads, scrubber-fitted vessels are economically advantageous. However, in high freight rate environments, non-scrubber vessels can become more cost-effective due to their lower hire expenses. In addition, the study reinforced the importance of accurate voyage estimation in making informed chartering decisions to maximize profitability. The graphical analysis provided a clear representation of cost and revenue structures, highlighting the key factors impacting vessel selection.

5.2 Implications

The findings of the study offer practical implications for various parties involved in the maritime sector, including shipowners, charterers and operators. For shipowners and operators, the results emphasize the benefits of selecting the optimal vessel for specific routes and cargo types, a decision-making process that is informed by economic and environmental factors. A structured approach to voyage estimation enables chartering managers to make more informed decisions regarding vessel selection, ensuring optimal cost-efficiency balance. Moreover, insights derived from this study can also benefit market analysts, who can utilize data concerning fuel efficiency and scrubber technology to improve their forecasts and investment strategies.

Considering these insights, stakeholders should adopt a strategy that is consistent with both market dynamics and regulatory developments. Shipowners should carefully evaluate the long-term viability of scrubber investments, considering potential regulatory changes and fuel price trends that could impact their cost advantage. Charterer, on the other hand, need to balance TCE performance with operating costs when selecting vessels, especially in volatile fuel markets. In addition, operators must implement adaptive strategies that allow flexibility in vessel deployment based on changing market conditions. This will ensure that cost efficiency and voyage profitability continue to be optimized. By integrating these considerations, industry players can improve decision-making and maintain a competitive edge in an evolving shipping landscape.

5.3 Assessments and Limitations

The study assessed the validity and practicality of the proposed methodology through multiple approaches. A meticulous, step-by-step breakdown of voyage calculations was provided to ensure transparency and replicability. Real-world voyage scenarios were analyzed to identify the impact of vessel selection on financial performance. Sensitivity analysis was performed to assess how changes in bunker prices and port costs affect the TCE results and influence selection. For instance, the TCE for the scrubber-equipped vessel decreases from approximately \$17,382/day to \$15,382/day as HSFO increases from \$455/MT to \$615/MT. In comparison, the TCE for the non-scrubber vessel decreases more steeply, from about \$16,575/day to \$13,000/day, as VLSFO prices increase from

\$495/MT to \$655/MT. These findings indicate that while scrubber-equipped vessels retain an advantage under stable HSFO pricing, the margin narrows considerably when fuel prices or charter rates increase. As such, vessel selection may shift when HSFO prices exceed \$600/MT or when market conditions drive up daily hire costs for scrubber-equipped tonnage. In a similar manner, if gross freight rate exceed \$39/MT, the TCE gap between vessels is further reduced, making vessel selection more sensitive to voyage duration and charter costs. These numerical thresholds underscore the sensitivity of profitability to market-driven variables and illustrate the scenarios in which vessel preference may be subject to alteration.

Additionally, a critical review of the model's limitations was conducted, acknowledging assumptions about market stability and vessel availability that may affect real-world applicability. A significant limitation was the dependency on the availability and accuracy of data, particularly real-time market data. The volatility of market conditions may result in discrepancies or gaps in data, which could potentially impact the reliability of the model. (Molvik & Stafseng, 2018). Additionally, the study did not fully account for unpredictable external factors, such as geopolitical events, economic downturns or extreme weather conditions. These can significantly disrupt vessel performance and profitability but are difficult to predict or model comprehensively.

A further limitation was the focus on dry bulk shipping. While the research provided valuable insights for this sector, the findings may not be easily transferrable to other shipping types, such as containers or wet shipping, without further modifications. In addition, the study did not examine niche markets or specific regional conditions that may have distinctive factors influencing vessel selection.

Lastly, the model's emphasis on quantifiable metrics may result in the neglect of qualitative factors, such as human judgment and decision-making experience. These factors also play a role in real-world vessel selection but are more challenging to capture within a purely data-driven framework. These limitations should be considered when interpreting the study's findings. (Choong-ho & Keun-Sik, 2024)

5.4 Future Research

Future research directions may be possible to develop building on this study by incorporating a broader dataset with multiple vessel sizes and typer to validate the findings across a range of different market segments. An expanded analysis, including time charter

scenarios, could provide a more comprehensive vessel selection framework. This could entail the evaluation of vessel selection under index-linked time charter hire rates with floor and ceiling rate mechanisms, which offer flexibility in the management of market volatility. This approach would enable charterers and owners to hedge against extreme rate fluctuations while maintaining predictable revenue streams.

Further research can also explore additional key areas. The adoption of alternative fuels could be investigated to assess their economic viability and feasibility as sustainable shipping solutions. Additionally, a more in-depth analysis of regulatory impacts, including the emerging IMO regulations, carbon taxes, emissions trading schemes and EUAs tickets could provide valuable insights into how such policies affect vessel selection and profitability.

The incorporation of machine learning and AI-driven algorithms into advanced optimization models could further improve the predictive accuracy of TCE performance, thereby optimizing vessel selection under varying market conditions.

This research provides a foundation for further exploration of vessel selection strategies, contributing to the continued improvement of the profitability and sustainability of the dry bulk shipping industry.

7. Appendix

7.1 Voyage estimation vessel 1

MV "UTOPIA"

CallSign: 5LND4

Sub type: Bulk Carrier

Gears: 4x30T Crane 4x15cbm Grabs

Built: 2020 by OSHIMA SAKAI

Flag: Liberia

DWT/Draft: 64,499 MT DWT / 13.54 m SSW

TPC / TPI: 60.93 MT / 154.76 LT at full summer draft

LOA/Beam: 199.95 m (loa) / 32.26 m (beam)

LBP: 196.8 m

Int'l tonnage: 36,256 GT / 21,296 NT

Suez: 37336.2 GT / 33713.7 NT

Summer salt: 64,499 MT DWT / 13.54 m SSW / 60.93 TPC

CO2 fitted

AHL fitted

Scrubber Fitted

Open hatches

Depth moulded: 19.28 m

IFO capacity: 5 MT

MD/GO capacity: 0 MT

FW capacity: 382 m³

Speed/cons:

Laden: abt 13.5 kts on IFO 24 MT () +MD/GO 0.1 MT at sea

Ballast: abt 14 kts on IFO 22 MT () +MD/GO 0.1 MT at sea

Laden: abt 12 kts on IFO 19 MT () +MD/GO 0.1 MT at sea

Ballast: abt 12.5 kts on IFO 17 MT () +MD/GO 0.1 MT at sea

Port idle: 3.0 IFO + 0.1 MD/GO (MT/24hours)

Above speed / consumption in good weather conditions upto/incl Beaufort Force 4 and

Douglas Sea State 3 with no adverse current and no negative influence of swell.

1. Deadweight Cargo Capacity Calculation

The MV UTOPIA has DWT 64,499 mt and 13.54 m SSW draft. However, we have draft limitation. So: $13.54 - 10.00 = 3.54 \text{ m} = 354 \text{ cm}$

Then: $354 \text{ cm} \times (\text{TPC} = 60.93) = 21,569.22$

New DWT: $64,499.00 - 21,569.22 = 42,929.78 \text{ mt}$

But we must consider the water density impacts on the DWT.

When a vessel moves from freshwater to seawater, it naturally rises because seawater is denser. This means that if the vessel is loaded to the summer load line in freshwater, it will be higher when it enters seawater, reducing the amount of cargo it can carry and resulting in loss of revenue. To avoid this, it is important to consider the FWA, which helps ensure that the vessel is loaded efficiently. In this instance, the specified draft is based on freshwater, which further restricts the draft limitations. To accurately determine the vessel's loading capacity, we must recalculate the draft limitation for SSW, ensuring the vessel can carry its maximum cargo capacity safely (Rahaman, 2018):

$10.00 \div 1.025 = 9.756 \text{ m. SSW draft}$

The new DWT is: $64,499.00 - (13.54 \text{ m} - 9.756 \text{ m} \times 60.93) = 41,443.09 \text{ mt}$

2. Time Duration:

Laden: Distance \div (Speed \times 24h) =

$7,373 \text{ nm} \div (12.00 \text{ knots} \times 24\text{h}) = 25.60 + 10\% = 28.16 \text{ days}$

Ballast: Distance \div (Speed \times 24h) =

$308 \text{ nm} \div (12.50 \text{ knots} \times 24\text{h}) = 1.02 + 10\% = 1.13 \text{ days}$

Passing: Las Palmas for bunkering call 12h=0.50 days

Loading Port at San Lorenzo: $40,071 \text{ mt} \div 8,000 = 5.01 \text{ days}$

Discharge Port at Damietta: $40,071 \text{ mt} \div 5,000 = 8.01 \text{ days}$

Total: 42.81 days plus 2 idle days 44.81 days

3. Bunkering Consumption:

Laden: 28.16 days \times 19mt = 535.05mt IFO

28.16 days \times 0.1mt = 2.82mt MDO

Ballast: 1.13 days \times 17mt = 19.20mt IFO

1.13 days \times 0.1mt = 0.113mt MDO

Loading Port: $5.01 \text{ days} \times 5\text{mt} = 25.05\text{mt MDO}$

$5.01 \text{ days} \times 0.1\text{mt} = 0.50\text{mt MDO}$

Discharge Port: $8.01 \text{ days} \times 5\text{mt} = 40.05\text{MDO}$

$8.01 \text{ days} \times 0.1\text{mt} = 0.80\text{mt MDO}$

Passing Las Palmas for bunkering call: $0.50 \times 2.8 = 1.40\text{MDO}$

Idle: $2\text{days} \times 3\text{mt} = 6\text{mt IFO}$

$2 \text{ days} \times 0.1 = 0.20\text{mt MDO}$

Total IFO $535.05 + 19.20 + 6 = 560.25$

Total MGO $2.82 + 0.11 + 25.05 + 0.50 + 40.07 + 0.80 + 0.2 + 1.40 = 70.95$

Total = 631.20mt .

4. New DWCC:

DWT: $41,443.09\text{mt}$

590mt Bunkering

382mt Freshwater

400mt Constant

The New DWCC is $40,071\text{mt}$

1. Scrubber-equipped vessel

Vessel's name: C5

Vessel's type: C6

NET DWAT: C7

Constants: C8

Fuels: C9

Ballast and fresh water: C10

DWCC: $C11 = C7 - C8 - C9 - C10$

2. SPEED & CONSUMPTIONS

SPEED BALLAST: C18

SPEED LADEN: C19

CONSUMPTION FO MGO

BALLAST: C23 FOR FO AND D23 FOR MGO

LADEN: C24 FOR FO AND D24 FOR M.G.O

PORT1 or IDLE: C25 FOR FO AND D25 FOR MGO

PORT2 or IDLE: C26 FOR FO AND D26 FOR MGO

PORT3 or IDLE: C27 FOR FO AND D27 FOR MGO

CANAL: C28 FOR FO AND D28 FOR MGO

ECA BALLAST: C29 FOR FO AND D29 FOR MGO

ECA LADEN: C30 FOR FO AND D30 FOR MGO

3. FUEL PRICES

FO PRICE: / HSFO C35

MGO PRICE: C36

4. VOYAGE

VOYAGE: J5

DATE: J6, (COMMENCEMENT)

CARGO: J7

QUANTITY: J8=C11

FREIGHT RATE: J9

COMMISSION: J10,

1ST DISCHARGE: M5

5.VOYAGE DURATION

LEG: I19, I22, I25

ECA: I20, I23, I26

NON ECA: I21, I24, I27

FROM: J19, J22, J25

TO: K19, K22, K25

MILES: L19, L22, L25

- $L19 = L20 + L21$, L20 ECA MILES AND L21 NON-ECA MILES
- $L22 = L23 + L24$, L23 ECA MILE AND L24 NON-ECA MILES
- $L25 = L26 + L27$, L26 ECA MILE AND L27 NON-ECA MILES

BALLAST/LADEN: M19, M22, M25

Steaming days: N19, N22, N25

- $N19 = \text{IF}(M19="B"; L19/(24*\$C\$18); \text{IF}(M19="L"; L19/(24*\$C\$19);)) * 1,1$
- $N20 = \text{IF}(M19="B"; L20/(24*\$C\$18); \text{IF}(M19="L"; L20/(24*\$C\$19);)) * 1.1$
- $N21 = \text{IF}(M19="B"; L21/(24*\$C\$18); \text{IF}(M19="L"; L21/(24*\$C\$19);)) * 1,1$
- $N22 = \text{IF}(M22="B"; L22/(24*\$C\$18); \text{IF}(M22="L"; L22/(24*\$C\$19);)) * 1,1$
- $N23 = \text{IF}(M22="B"; L23/(24*\$C\$18); \text{IF}(M22="L"; L23/(24*\$C\$19);)) * 1.1$
- $N24 = \text{IF}(M22="B"; L24/(24*\$C\$18); \text{IF}(M22="L"; L24/(24*\$C\$19);)) * 1,1$
- $N25 = \text{IF}(M25="B"; L25/(24*\$C\$18); \text{IF}(M25="L"; L25/(24*\$C\$19);)) * 1.1$
- $N26 = \text{IF}(M25="B"; L26/(24*\$C\$18); \text{IF}(M25="L"; L26/(24*\$C\$19);)) * 1.1$

- $N27 = \text{IF}(M25 = "B"; L27 / (24 * \$C\$18); \text{IF}(M25 = "L"; L27 / (24 * \$C\$19);)) * 1.1$

Totals:

- Total miles (kn): $L30 = L19 + L22 + L25$
- Total steaming days: $N30 = N19 + N22 + N25$

6. ESTIMATED DAYS IN PORTS

LOADING RATE: J35

DISHARGING RATE: J36

PORT: I39-I41

ARRIVAL DATE: J39-J41

- $J39 = J6 + N19$
- $J40 = M39 + N22$
- $J41 = M40 + N25$

DAYS TO: K39-K41

- $K39 = (\text{IF}(O39 = "L"; \$J\$8 / \$J\$35; \text{IF}(O39 = "D"; \$M\$5 / \$J\$36; \text{IF}(O39 = "C"; \$M\$6 / \$J\$36;))))$
- $K40 = \text{IF}(O40 = "L"; \$J\$8 / \$J\$35; \text{IF}(O40 = "D"; \$M\$5 / \$J\$36; \text{IF}(O40 = "C"; \$M\$6 / \$J\$36;))))$
- $K41 = \text{IF}(O41 = "L"; \$J\$8 / \$J\$35; \text{IF}(O41 = "D"; \$M\$5 / \$J\$36; \text{IF}(O41 = "C"; \$M\$6 / \$J\$36;))))$

DA's: N39-N41

TYPE: O39-O41

TOTAL: J44

- $J44 = \text{SUM}(K39:K41)$

7. Fuel expenses

Voyage consumption

Leg: T9-T11

- T9= 1st voy
- T10= 2nd voy
- T11= 3rd voy

Days: U9-U11

- U9=N19
- U10=N22
- U11=N25

FO mt CONSUMPTION: V9-V11

- $V9 = IF(M19 = "B"; \$C\$23 * N21; \$C\$24 * N21)$
- $V10 = IF(M22 = "B"; \$C\$23 * N24; \$C\$24 * N24)$
- $V11 = IF(M25 = "B"; \$C\$23 * N27; \$C\$24 * N27)$

MGO mt CONSUMPTION: W9-W11

- $W9 = IF(M19 = "B"; \$D\$23 * N21; \$D\$24 * N21)$
- $W10 = IF(M22 = "B"; \$D\$23 * N24; \$D\$24 * N24)$
- $W11 = IF(M25 = "B"; \$D\$29 * N26; \$D\$30 * N26)$

FO US\$: X9-X11

- $X9 = V9 * \$C\35
- $X10 = V10 * \$C\35

- $X11 = V11 * \$C\35

MGO US\$: Y9-Y11

- $Y9 = W9 * \$C\36
- $Y10 = W10 * \$C\36
- $Y11 = W11 * \$C\36

Port consumption

Leg: T14-T16

- $T14 = I39$
- $T15 = I40$
- $T16 = I41$

Days: U14-U16

- $U14 = K39 + L39$
- $U15 = K40 + L40$
- $U16 = K41 + L41$

FO mt CONSUMPTIONS: V14-V16

MGO mt CONSUMPTIONS: W14-W16

- $W14 = (U14 * C25) + (U14 * D25)$
 $W15 = U15 * D26$
- $W15 = (U15 * C28)$
- $W16 = (U16 * C26) + (U16 * D26)$

FO US\$: X14-X16

- $X14 = V14 * \$C\35
- $X15 = V15 * \$C\35
- $X16 = V16 * \$C\35

MGO US\$: Y14-Y16

- $Y14 = W14 * \$C\36
- $Y15 = W15 * \$C\36
- $Y16 = W16 * \$C\36

Idle Consumption

Days: $U19 = Y50$

FO mt: $V19 = U19 * C27$

MGO mt: $W19 = U19 * D27$

FO US\$: $X19 = V19 * C35$

MGO US\$: $Y19 = W19 * C36$

Canal Consumption

Days: $U20 = Y51$

FO mt: $V20 = U20 * C28$

MGO mt: $W20 = U20 * D28$

FO US\$: $X20 = V20 * C35$

MGO US\$ $Y20 = W20 * C36$

Total Consumption

- $V22 = \text{SUM}(V9:V11) + \text{SUM}(V14:V21)$
- $W22 = \text{SUM}(W9:W11) + \text{SUM}(W14:W21)$
- $X22 = \text{SUM}(X9:X11) + \text{SUM}(X14:X21)$
- $Y22 = \text{SUM}(Y9:Y11) + \text{SUM}(Y14:Y21)$

8. TOTAL EXP & TOTAL DAYS**Expenses:**

OPEX= U36

Capital expenses:

INSURANCE: U41

LOAN: U42

TOTAL CAPITAL EXPENSES

- $U43 = \text{SUM}(U41:U42)$

Voyage costs:

Loading Port Cost: $Y36 = N39$

Discharging Port Cost: $Y37 = N40$

Passing Bunker Supply: Y38

BUNKERS: $Y39 = ((X22 + Y22))$

EXTRA INSURANCE: Y40

PILOTS FEES: Y41

DESPATCH: Y42

MISCELLANEOUS: Y43

TOTAL VOY. EXPENSES: $Y44 = \text{SUM}(Y36:Y43)$

Days:

TOTAL STEAMING DAYS $Y48 = N30$

PORT TIME: $Y49 = J44$

IDLE: Y50

CANAL: Y51

TOTAL: $Y52 = \text{SUM}(Y48:Y51)$

9. Revenues & Returns

Revenues:

GROSS FREIGHT: $J60 = J8 * J9$

DEMURRAGE: J61

EXTRA INCOME: J62

GROSS INCOME: $J63 = \text{SUM}(J60:J62)$

LESS COMMISSION: $J64 = J10 * (J60 + J61)$

LESS FREIGHT TAX: $J65 = J60 * K65$

Tax percentage: K65

NET REVENUE: $J66 = J63 - J64 - J65$

Returns:

VOYAGE SURPLUS: $N60 = J66 - Y44$

DAYS: $N61 = Y52$

TCE: $N62 = (J66 - Y44) / Y52$

10. CHARTER-IN

Charter-In: E56 specifies if the vessel is chartered in

Net Freight Income: $D60 = IF(E56 = "Y"; J66; "")$

Hire Freight Rate: $D61 = D62 / J8$

Hire Total: $D62 = D64 - Y44$

Hire Cost per Day: $D63 = D62 / Y52$

Hire Operation Total Expenses: $D64 = D60 - D65$

Hire operation Net Income: $D65 = D60 * D66$

7.2 Voyage estimation Vessel 2

MV "TRUONG MINH SUCCESS

CallSign: XVKA7

Sub type: Bulk Carrier

Gears: 4x35T Crane 4x12cbm Grabs

Built: 2014 by IMABARI SHIN KASADO

Flag: Viet Nam

DWT/Draft: 61,346 MT DWT / 13.01 m SSW

TPC / TPI: 61.4 MT / 155.96 LT at full summer draft

LOA/Beam: 199.98 m (loa) / 32.24 m (beam)

LBP: 195 m

Int'l tonnage: 34,764 GT / 20,200 NT

Tropical fresh: 62,908 MT / 13.57 m / 61.561.50 TPC

Summer fresh: 61,284 MT / 13.3 m / 61.561.50 TPC

Tropical salt: 61,346 MT / 13.01 m / 61.561.50 TPC

Summer salt: 61,346 MT DWT / 13.01 m SSW / 61.40 TPC

NOT CO2 fitted

Depth moulded: 18.6 m

IFO capacity: 6 MT

MD/GO capacity: 0 MT

FW capacity 311.58 m³

Speed/cons:

Laden: abt 13.7 kts on IFO 32.3 MT () +MD/GO 0.1 MT at sea

Ballast: abt 14.3 kts on IFO 30.3 MT () +MD/GO 0.1 MT at sea

Laden: abt 12.5 kts on IFO 23 MT () +MD/GO 0.1 MT at sea

Ballast: abt 13 kts on IFO 21 MT () +MD/GO 0.1 MT at sea

Port idle: 2.7 IFO + 0.1 MD/GO (MT/24hours)

Above speed / consumption in good weather conditions upto/incl Beaufort Force 4 and Douglas Sea State 3 with no adverse current and no negative influence of swell.

1. Deadweight Cargo Capacity Calculation

The MV TRUONG MINH SUCCESS has DWT 61,346 mt and 13.01 m SSW draft.

Then: $301 \text{ cm} \times (\text{TPC} = 61.4) = 18,481.4$

New DWT: $61,346 - 18,481.4 = 42,864.6 \text{ mt}$

But we must consider the water density impacts on the DWT.

So, we must re-calculate the draft limitation to SSW:

$10.00 \div 1.025 = 9.756 \text{ m. SSW draft}$

The new DWT is: $61,346 - (13.01 \text{ m} - 9.756 \text{ m} \times 61.4) = 41,366.44 \text{ mt}$

2. Time Duration:

Laden: Distance \div (Speed x 24h) =

$7,373 \text{ nm} \div (12.50 \text{ knots} \times 24\text{h}) = 24.58 + 10\% = 27.03 \text{ days}$

Ballast: Distance \div (Speed x 24h) =

$308 \text{ nm} \div (13.00 \text{ knots} \times 24\text{h}) = 0.99 + 10\% = 1.09 \text{ days}$

Loading Port at San Lorenzo: $40,019 \text{ mt} \div 8,000 = 5.00 \text{ days}$

Discharge Port at Damietta: $40,019 \text{ mt} \div 5,000 = 8.00 \text{ days}$

Passing Las Palmas for bunkering call: 0.50 days

Total: 41.62 days plus 2 idle days 43.62 days

3. Bunkering Consumption:

Laden: 27.03 days x 23mt = 621.79mt IFO

$$27.03 \text{ days} \times 0,1\text{mt} = 2.70\text{mt MDO}$$

Ballast: $1.09 \text{ days} \times 21\text{mt} = 22.80\text{mt IFO}$

$$1.09 \text{ days} \times 0,1\text{mt} = 0.11\text{mt MDO}$$

Loading Port: $5.00 \text{ days} \times 5.8\text{mt} = 29.01\text{mt IFO}$

$$5.00 \text{ days} \times 0,1\text{mt} = 0.50\text{mt MDO}$$

Discharge Port: $8.00 \text{ days} \times 5.8\text{mt} = 46.42\text{mt IFO}$

$$8.00 \text{ days} \times 0,1\text{mt} = 0.80\text{mt MDO}$$

Passing Las Palmas bunkering call: $0.50\text{days} \times 2.7\text{mt}=1.35 \text{ MDO}$

Idle: $2\text{days} \times 2.7\text{mt}=5.4\text{mt IFO}$

$$2 \text{ days} \times 0.1=0.20\text{mt MDO}$$

$$\text{Total IFO } 621.79+22.80+29.01+46.42+5.4=725.43$$

$$\text{Total MGO } 2.70+0.11+0.50+0.80+1.35+0.2=5.66$$

$$\text{Total}= 731.09$$

4. New DWCC:

DWT: 41,366.44mt

684mt Bunkering

311mt Freshwater

400mt Constant

The New DWCC is 40,019mt ('Bunkerwire', 2025)

1. Non-scrubber vessel

Vessel's name: C5

Vessel's type: C6

NET DWAT: C7

Constants: C8

Bunkers: C9

Ballast and Fresh water: C10

DWCC: C11= C7-C8-C9-C10

2. SPEED & CONSUMPTIONS

SPEED BALLAST: C18

SPEED LADEN: C19

CONSUMPTION FO and MGO

BALLAST: C23 FOR FO AND D23 FOR MGO

LADEN: C24 FOR FO AND D24 FOR MGO

PORT1 or IDLE: C25 FOR FO AND D25 FOR MGO

PORT2 or IDLE: C26 FOR FO AND D26 FOR MGO

PORT3 or IDLE: C27 FOR FO AND D27 FOR MGO

CANAL: C28 FOR FO AND D28 FOR MGO

ECA BALLAST: C29 FOR FO AND D29 FOR MGO

ECA LADEN: C30 FOR FO AND D30 FOR MGO

3. FUEL PRICES

FO PRICE US\$ / HSFO: C35

MGO PRICE US\$: C36

4. VOYAGE

VOYAGE: J5

DATE: J6, (COMMENCEMENT)

CARGO: J7

QUANTITY: J8=C11

FREIGHT RATE: J9

COMMISSION: J10,

1ST DISCH.: M5

2ND DISCH.: M6

5. VOYAGE DURATION

LEG: I19, I22, I25

ECA: I20, I23, I26

NON ECA: I21, I24, I27

FROM: J19, J22, J25

TO: K19, K22, K25

MILES (kn): L19, L22, L25

- L19= L20+L21, L20 ECA MILES AND L21 NON-ECA MILES
- L22=L23+L24, L23 ECA MILE AND L24 NON-ECA MILES
- L25= L26+L27, L26 ECA MILE AND L27 NON-ECA MILES

BALLAST/LADEN: M19, M22, M25

Steaming days: N19, N22, N25

- $N19 = IF(M19="B"; L19/(24*SC\$18); IF(M19="L"; L19/(24*SC\$19);)) * 1,1$
- $N20 = IF(M19="B"; L20/(24*SC\$18); IF(M19="L"; L20/(24*SC\$19);)) * 1.1$
- $N21 = IF(M19="B"; L21/(24*SC\$18); IF(M19="L"; L21/(24*SC\$19);)) * 1,1$
- $N22 = IF(M22="B"; L22/(24*SC\$18); IF(M22="L"; L22/(24*SC\$19);)) * 1,1$
- $N23 = IF(M22="B"; L23/(24*SC\$18); IF(M22="L"; L23/(24*SC\$19);)) * 1.1$
- $N24 = IF(M22="B"; L24/(24*SC\$18); IF(M22="L"; L24/(24*SC\$19);)) * 1,1$

- $N25 = IF(M25="B"; L25/(24* \$C\$18); IF(M25="L"; L25/(24* \$C\$19);)) * 1.1$
- $N26 = IF(M25="B"; L26/(24* \$C\$18); IF(M25="L"; L26/(24* \$C\$19);)) * 1.1$
- $N27 = IF(M25="B"; L27/(24* \$C\$18); IF(M25="L"; L27/(24* \$C\$19);)) * 1.1$

TOTAL:

- Total miles (kn): $L30 = L19 + L22 + L25$
- Total steaming days: $N30 = N19 + N22 + N25$

6. ESTIMATED DAYS IN PORTS

LOADING RATE: J35

DISHARGING RATE: J36

PORT: I39-I41

ARRIVAL DATE: J39-J41

- $J39 = J6 + N19$
- $J40 = M39 + N22$
- $J41 = M40 + N25$

DAYS TO: K39-K41

- $K39 = (IF(O39="L"; \$J\$8/\$J\$35; IF(O39="D"; \$M\$5/\$J\$36; IF(O39="C"; \$M\$6/\$J\$36;))))$
- $K40 = IF(O40="L"; \$J\$8/\$J\$35; IF(O40="D"; \$M\$5/\$J\$36; IF(O40="C"; \$M\$6/\$J\$36;)))$
- $K41 = IF(O41="L"; \$J\$8/\$J\$35; IF(O41="D"; \$M\$5/\$J\$36; IF(O41="C"; \$M\$6/\$J\$36;)))$

DA's: N39-N41

TYPE: O39-O41

TOTAL: J44

- J44=SUM (K39:K41)

7. Fuel expenses

Voyage consumption:

Leg: T9-T11

- T9= 1st voy
- T10= 2nd voy
- T11= 3rd voy

Days: U9-U11

- U9=N19
- U10=N22
- U11=N25

FO mt CONSUMPTION: V9-V11

- V9=IF(M19="B";\$C\$23*N21;\$C\$24*N21)
- V10 =IF(M22="B";\$C\$23*N24;\$C\$24*N24)
- V11 =IF(M25="B";\$C\$23*N27;\$C\$24*N27)

MGO mt CONSUMPTION: W9-W11

- W9=IF(M19="B";\$D\$23*N21;\$D\$24*N21)
- W10=IF(M22="B";\$D\$23*N24;\$D\$24*N24)
- W11=IF(M25="B";\$D\$29*N26;\$D\$30*N26)

FO US\$: X9-X11

- $X9 = V9 * \$C\35
- $X10 = V10 * \$C\35
- $X11 = V11 * \$C\35

MGO US\$: Y9-Y11

- $Y9 = W9 * \$C\36
- $Y10 = W10 * \$C\36
- $Y11 = W11 * \$C\36

Port consumptions:

Leg: T14-T16

- $T14 = I39$
- $T15 = I40$
- $T16 = I41$

Days: U14-U16

- $U14 = K39 + L39$
- $U15 = K40 + L40$
- $U16 = K41 + L41$

FO mt CONSUMPTIONS: V14-V16

- $V14 = U14 * C25$
- $V16 = U16 * C26$

MGO mt CONSUMPTIONS: W14-W16

- $W14 = U14 * D25$
- $W15 = U15 * C27$

- $W16=U16*D27$

FO US\$: $X14-X16$

- $X14=V14*\$C\35

- $X15=V15*\$C\35

- $X16=V16*\$C\35

MGO US\$: $Y14-Y16$

- $Y14=W14*\$C\36

- $Y15=W15*\$C\36

- $Y16=W16*\$C\36

Idle consumptions:

Days: $U19=Y50$

FO mt: $V19=U19*C27$

MGO mt: $W19=U19*D25$

FO US\$: $X19=V19*C35$

MGO US\$: $Y19=W19*C36$

Canal consumptions:

Days: $U20=Y51$

FO mt: $V20=U20*C28$

MGO mt: $W20=U20*D28$

FO US\$: $X20=V20*C35$

MGO US\$ $Y20=W20*C36$

Total Consumptions:

- $V22 = \text{SUM}(V9:V12) + \text{SUM}(V14:V21)$
- $W22 = \text{SUM}(W9:W12) + \text{SUM}(W14:W21)$
- $X22 = \text{SUM}(X9:X12) + \text{SUM}(X14:X21)$
- $Y22 = \text{SUM}(Y9:Y12) + \text{SUM}(Y14:Y21)$

8. TOTAL EXP. & TOTAL DAYS**Expenses:**

OPEX= U36

Capital expenses:

INSURANCE: U41

LOAN: U42

TOTAL CAPITAL EXPENSES

- $U43 = \text{SUM}(U41:U42)$

Voyage costs:

LOADING PORT COST: $Y36 = N39$

DISHARGING PORT: $Y37 = N41$

PASSING BUNKER SUPPLY: $Y38 = N40$

BUNKERS: $Y39 = (X22 + Y22)$

EXTRA INSURANCE: Y40

PILOTS FEES: Y41

DESPATCH: Y42

MISCELLANEOUS: Y43

TOTAL VOY. EXPENSES: $Y44 = \text{SUM}(Y36:Y43)$

Days:

TOTAL STEAMING DAYS $Y48 = N30$

PORT TIME: $Y49 = J44 + K44$

IDLE: Y50

CANAL: Y51

TOTAL: $Y52 = \text{SUM}(Y48:Y51)$

9. Revenues and Returns

Revenue:

GROSS FREIGHT: $J60 = J8 * J9$

DEMURRAGE: J61

EXTRA INCOME: J62

GROSS INCOME: $J63 = \text{SUM}(J60:J62)$

LESS COMMISSION: $J64 = J10 * (J60 + J61)$

LESS FREIGHT TAX: $J65 = J60 * K65$

Tax percentage: K65

NET REVENUE: $J66 = J63 - J64 - J65$

Returns:

VOYAGE SURPLUS: $N60 = J66 - Y44$

DAYS: $N61 = Y52$

TCE: $N62 = (J66 - Y44) / Y52$

10. CHARTER-IN

Charter-In: E56 specifies if the vessel is chartered in

Net Freight Income: $D60 = IF(E56 = "Y"; J66; "")$

Hire Freight Rate: $D61 = D62 / J8$

Hire Total: $D62 = D64 - Y44$

Hire Cost per Day: $D63 = D62 / Y52$

Hire Operation Total Expenses: $D64 = D60 - D65$

Hire operation Net Income: $D65 = D60 * D66$

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